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J. W. POWELL, DIRECTOR

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SYSTEMATIC REVIEW

OF OUR

PRESENT KNOWLEDGE OF FOSSIL INSECTS

INCLUDING

MYRIAPODS AND ARACHNIDS

BY

SAMUEL HUBBARD SCUDDER

WASHINGTON
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LETTER OF TRANSMITTAL.

CAMBRIDGE, MASS., *January* 13, 1886.

SIR: I have the honor to transmit for publication as a bulletin of the Survey the inclosed systematic review of our present knowledge of fossil insects, including myriapods and arachnids.

While much fuller in the modern orders and families, the following pages represent the English text furnished to Dr. Zittel for his Handbuch der Palæontologie, where the section forms the closing pages of the second part of the first volume (pp. 721–831) and is accompanied by more than two hundred illustrations. The present bulletin is issued, with the concurrence of Dr. Zittel and the publisher of the Handbuch, for the convenience of English readers. A French version, under the auspices of M. Barrois, is also in course of simultaneous publication. The present is its original form and is the authoritative English edition.

I am, very truly, yours,

SAMUEL H. SCUDDER.

Hon. J. W. POWELL,
Director United States Geological Survey.

SYSTEMATIC REVIEW OF FOSSIL INSECTS.

MYRIAPODA.

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CHARACTERISTICS AND PHYLOGENY.

Myriapoda are vermiform articulates in which the head proper is composed of a single mass (sometimes supplemented by subsidiary parts borrowed from the segments immediately succeeding the head), while the rest of the body is composed of a series, generally of a long series, of very similar rings, each bearing one or two pairs of jointed legs, terminating in a claw, with rare exceptions single. No thorax is differentiated. The head is furnished with short and generally very simple antennæ, agglomerated ocelli, and two pairs of movable organs forming the mouth. In one group (Chilopoda) two pairs of appendages on succeeding rings become subservient to manducation. Respiration is effected through spiracles on the body segments.[1] The body is usually hard and chitinous.

Our knowledge of the morphology, systematic position, and extent of the Myriapoda has been greatly increased within a recent period. The discovery of the minute Pauropus by Lubbock and the study of this and allied forms by Ryder and others have led to the establishment of the Pauropoda as a type of living myriapods of equal taxonomic value with the two groups Chilopoda and Diplopoda, which had long been looked upon as the only divisions of the group. Modern investigations into the structure of the anomalous Peripatus have extended our ideas concerning the types allied to the Myriapoda; while the strange forms revealed by recent researches in the Carboniferous and Devonian faunas have compelled us to recognize a wider range in its structure and a multiplication of its primary groups. The relations of ancient to modern forms of life prove far more important and interesting in the Myriapoda than in either the Arachnida or the Hexapodæ. That these relations are equally puzzling will appear from a brief review of the structure and development of the different groups.

In the early life of the Pauropoda and of the Diplopoda we have what may be fairly considered a true larval form, in which, for a brief period after leaving the egg, the body, much shorter than in after-life, is provided with three pairs of legs borne upon the anterior segments of the body. These segments are never more fully provided with legs, though most of the segments posterior to them, both those which exist during this larval period and those which originate subsequently, bear each two pairs. In the Chilopoda, on the other hand, although the appendages of the anterior segments develop earlier than those behind them, there is no true larval condition, or perhaps one may say a larval condition is permanent, in that the same anterior legs become early and permanently developed as organs subsidiary to manducation, while each segment of the hinder part of the body develops only a single pair of legs.

The larval condition and resultant more or less highly developed metamorphosis of the higher Hexapoda have been looked upon by many as secondary after-developments, which therefore in no sense give any clew to the historical development of the group, such as we frequently find mirrored in the embryonic growth of other animals. This view seems to be supported by a comparison of the modern and ancient types of Myriapoda. The larval characteristics of the young of living types of Myriapoda, marvelously analogous in their main features to those of the larvæ of even the higher Hexapoda, are confined to the apodal nature of the abbreviated abdomen, and more particularly to the specialized development of appendages on the segments directly

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[1] Tracheal openings have not been observed, however, in the Pauropoda.

following the head. This specialized condition of the anterior segments is, in a sense, analogous to the structure of the thorax of the Hexapoda, and is persistent throughout life: in the Chilopoda in a marked manner, in the other groups by the isolation of these segments as bearing each but a single pair of legs. Now, nothing of this specialization appears in the Paleozoic types, of which of course we know only the mature forms; but the segments following the head differ in no point whatever from those of the remainder of the body in the character and number of their appendages. In one type, the Archipolypoda, corresponding in a measure to the living type of Diplopoda, two pairs of legs are borne on every segment; while on each segment of the other, the Protosyngnatha, corresponding in a similar way to the Chilopoda, a single pair of legs is found. If, then, we look upon the specialization of the segments (or the appendages of the segments) immediately following the head in living myriapodan types as a secondary development, or, we may say, as the initiatory stage in an acquiring metamorphosis, then we may perhaps consider the Archipolypoda as the true prototypes of the Diplopoda and possibly also of the Pauropoda, and the Protosyngnatha as the prototypes of the Chilopoda.

In this view, one principal distinction between the modern Diplopoda and Chilopoda is shown to have existed from Paleozoic times, viz, that in one group there are, over most of the body, to each dorsal scute two ventral scutes, each bearing a pair of legs; in the other group a single ventral scute with a single pair of legs; and it becomes interesting to inquire whether we can discover any indication of the condition of things from which this diversity of structure arose and what was the line of development through which it passed. It will also help to determine the question whether the dorsal or the ventral scutes of the Diplopoda are to be looked upon as the homologues of those of the Chilopoda; or, in other words, whether the dorsal scutes of the Diplopoda are compound or the ventral scutes of the same are to be looked upon as subsegments.

It should be remarked at the outset that what we know of the embryology of recent types shows that in the Diplopoda two pairs of legs, in the Chilopoda one pair, arise from each original body somite beyond the front portion of the body. This would indicate that the dorsal scutes of the two groups are homologous and that the ventral scutes of the Diplopoda should be looked upon as representing subsegments. This, however, is not the answer indicated by the paleontological evidence, nor is it what we should expect, among other things, from the presence of stigmata on each of the ventral scutes in Diplopoda.[1] All the Carboniferous Archipolypoda show a clear indication of the compound nature of the segments. Not only were the ventral scutes far more important and extensive than in the modern Diplopoda, but some at least of the genera, in addition to large stigmata outside the legs,

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[1] They are only borne in general on alternate segments in Chilopoda.

bore a pair of segmental organs next the medioventral line on each ventral scute; the dorsal scute was also distinctly divided into two areas, an anterior and a posterior. In some types this latter distinction was more marked than in others, in some being carried so far that under certain conditions of preservation one would readily take them to be entirely separate; and this indeed appears to be absolutely the case in the older Devonian forms, from the lower old red sandstone of Scotland. These show an apparently complete demarkation of the dorsal as well as of the ventral scutes of each segment, and present therefore a series of alternating larger and smaller segments, the larger bearing all the dorsal cuticular outgrowths, but each bearing a single pair of legs. Of this primal condition of the body segments the embryology of modern types gives no hint, its earliest indications showing nothing anterior to what must have been the condition of things wholly posterior to the Paleozoic epoch, at least so far as the diplopodan series is concerned; nothing anterior, indeed, to the fixed condition of the present type. This indicates that the present dorsal scutes of Diplopoda are compound and formed of two originally distinct scutes; and that, as a later development of a similar sort, the ventral scutes of the anterior segments have likewise consolidated and lost each one pair of appendages.

Under this view the line which we follow back from the Chilopoda through the Protosyngnatha is the more nearly allied to the simple stock type. Yet it is the other line which has been found earliest in the rocks, clearly showing that the actual origin of the myriapodan phylum must be looked for at the very first appearance of land animals; indeed, the evidence that some of the Carboniferous types were amphibious may warrant our belief that the type may have fairly originated among aquatic animals.

Fossil Myriapoda were first made known from the Carboniferous rocks when Westwood figured, in Brodie's work on the older fossil insects of England, the remains of what he supposed to be a lepidopterous larva. There had been indeed earlier references, by name merely, to Tertiary Myriapoda from amber and from Aix (by Serres), but it was not until the publications, thirty years ago, of Koch, Berendt, and Menge that the amber species were known, and to them hardly any additions have since been made. In 1859 Sir William Dawson published the first account of a Paleozoic myriapod recognized as such, and since 1868 our horizon, as regards the older forms, has been widened materially by the publications of Messrs. Dohrn, Meek and Worthen, Peach, Scudder, and Woodward, until to-day the number of forms known from Pretertiary deposits is nearly as great as that from the Tertiary.

The oldest known are those described by Page and by Peach from the lower old red sandstone of Scotland, two species belonging to the Archipolypoda. In the Carboniferous formation the Archipolypoda culminate, showing a considerable variety of generic types distinct from those of the Devonian and embracing nearly thirty species, of which by far the greater number come from America, and the few remaining ones from Great Britain, with possibly a single species from Germany. Four species, imperfectly known, which have been referred to Julus and which come from the Permian of Central Europe, may belong to the Archipolypoda. The only Mesozoic forms known are *Julopsis cretacea* of Heer, from Greenland, which is either an archipolypod or a diplopod (it is impossible to tell which), and the uncertain *Geophilus proavus* of Münster, from Solenhofen, which is probably to be looked upon as a nereid worm.

The Tertiary species are still known almost entirely from the work of Koch and Berendt and belong entirely to the Diplopoda and the Chilopoda, the larger proportion to the former. A few species, however, have been indicated from Aix, a single one described from the brown coal of Rott and one from the Green River deposits of North America.

The following table presents a view of the distribution of the Myriapoda in time:

Geological distribution of Myriapoda.[1]

Groups.	Paleozoic.			Mesozoic.			Cenozoic.				Modern period.
	Devonian.	Carboniferous.	Dyas.	Lias.	Jura.	Cretaceous.	Eocene.	Oligocene.	Miocene.	Pliocene.	
Protosyngnatha	......	1	......	......	......	......	......	......	......	......	0
Chilopoda	......	......	......	......	(1?)	......	......	17	......	......	......
Archipolypoda	2	31	(4?)	......	......	......	......	......	......	......	0
Diplopoda	......	......	......	......	......	(1?)	......	23	1	......	......
Pauropoda	......	......	......	......	......	......	......	......	......	......	......

[1] The figures represent the number of species.

1. Order **PROTOSYNGNATHA** Scudder.

Paleozoic myriapods, with a cylindrical, not very elongated body, composed of few segments, the head appendages borne upon a single apparent segment; each body segment, including those immediately behind the head, composed of a single dorsal and a single ventral plate of equal length and of subequal breadth; each segment has a pair of widely-separated, stout, fleshy legs; and, above, large tubercles supporting a cluster of long needles are arranged in longitudinal rows.

This group of ancient myriapods is known through a single form found sparingly in a single locality in America. It was at first looked upon as the caterpillar of a lepidopterous insect (as was also the case with the longest known archipolypod) and afterward as a worm. Its armature seems even stranger for a myriapod than the spines of the

Archipolypoda, and the intimate structure of the single needles is remarkably complicated.

Palæocampa Meek and Worthen. Body composed of ten segments; spreading fascicles of needle-like spines arranged in dorsolateral and lateral rows, one to a segment in each row; needles exceedingly slender, scarcely tapering, blunt at tip, and very regularly divided by longitudinal serrated ridges. The spines are only a tenth of a millimeter in diameter; those on the front segments are directed forward and those on the last segments backward, giving specimens which are well preserved a very close general resemblance to a caterpillar of the genus Arctia. *Palæocampa anthrax* Meek and Worthen, Mazon Creek, Ill.

2. Order **CHILOPODA** Latreille.

Body elongated, more or less depressed, of nearly uniform width, composed of many segments, the head appendages borne upon two or more apparent segments, the anterior feet being transformed into organs subsidiary to manducation; each body segment composed of a single large dorsal and almost equally large ventral plate connected by membranous cuticle, to which are attached a single pair of legs on each segment and a spiracle generally on alternate segments. The legs are, therefore, lateral and widely separated at base. No spines are present, but sometimes lateral expansions of the dorsal plate. Sexual organs at posterior extremity of body.

With the exception of the dubious *Geophilus proavus* Münster, from the Jura of Solenhofen, which is probably not a myriapod at all, the earliest appearance of this type of existing myriapods is in the amber deposits of Prussia, where a considerable number of species have been found, nearly equaling, indeed, the Diplopoda of the same deposits, although, at the present day, the latter group far outnumbers them. A few specimens referred to Scolopendra have been reported from other Tertiary beds in Europe.

Cermatiidæ.—Two species of Cermatia occur in amber.

Lithobiidæ.—A considerable number of species, all referred to Lithobius, have been found in amber. Koch and Berendt describe and figure three species, to which Menge adds seven others very briefly described in notes to Berendt's work. The genus is, therefore, the richest in species among Tertiary myriapods.

Scolopendridæ.—Menge describes a single species of Scolopendra from amber and mentions a second. Sendel also figures one from amber, and it is referred to by subsequent authors. According to Keferstein, Aldrovandus mentions the discovery of a fossil Scolopendra near Glarus, Switzerland, and Hope mentions one as found at Aix.

Geophilidæ.—Three species of Geophilus are briefly described by Menge from amber, but none of these have been figured. *Geophilus* *proavus* Münster, from the Jura of Solenhofen, is, as stated above, dubious, but, if it belongs to the myriapods, it will probably fall in this place.

3. Order **ARCHIPOLYPODA** Scudder.

Paleozoic myriapods, with a fusiform elongated body, largest at the middle of the anterior half or third, composed of many segments; the head appendages borne upon a single apparent segment; the body segments, including those immediately behind the head, composed of a pair of ventral plates and a more or less divided dorsal plate, the latter occupying the upper surface and most of the sides of the body and divided more or less conspicuously into a ridged anterior and a lower posterior portion, the anterior frequently bearing spines or tubercles; the ventral plates as broad as the body, each bearing a pair of long corneous legs approximated at base and furnished outside of them with large spiracles, the mouth of which lies transverse to the body.

This is the most important group of ancient myriapods, having been well represented in the Paleozoic rocks, though unknown later. Indeed, with a single exception, all the known Paleozoic myriapods belonged to this type, and several families are known, of which one belonged exclusively to the Devonian. The Carboniferous Archipolypoda appear to have been far more numerous in the New than in the Old World.

1. Family **Archidesmidæ** Peach.

Dorsal plates hardly consolidated, the two portions appearing as if forming completely distinct parts, but the anterior marked by its greater importance and development. Body supplied with more or less marked laterally expanding lamellæ on the anterior division of the segments.

This group of ancient myriapods is confined, as far as known, to the Devonian formations of Scotland.

Kampecaris Page. Body cylindrical or slightly depressed, tapering but little anteriorly; lateral lamellæ inconspicuous, the anterior subsegments not greatly larger than the posterior. *Kampecaris Forfarensis* Page, from the lower old red sandstone of Forfarshire, Scotland. This species was taken by Page for an isopod crustacean, but referred to its true position by Peach.

Archidesmus Peach. Body fusiform, depressed, the anterior subsegment much larger than the posterior, its pleural walls produced laterally into large rounded lamellæ. *Archidesmus Macnicoli* Peach, from the same locality as the preceding.

2. Family **Euphoberidæ** Scudder.

Dorsal plates more or less closely consolidated, but distinctly separable into two portions, one much more elevated than the other. Body armed with large spines, often forked, occasionally reduced to broad tubercles, extending in several longitudinal series.

This family of Carboniferous Myriapoda includes the gigantic bristling species, some of which, at least, were amphibious, being provided with segmental organs, which were apparently branchial in character, besides ordinary spiracles, and with lamellate legs adapted for either aquatic or terrestrial locomotion. They appear to have been far more abundant in the New World than in the Old, and in the latter are little or not at all known outside of Great Britain.

Acantherpestes Meek and Worth. Spines bifurcate at tip and arranged in dorsal, pleurodorsal, and lateral rows; segments three or more than three times as broad as long. *Acantherpestes major* Meek and Worth., Mazon Creek. This species attained the extraordinary length of three decimeters and was armed with coarse branching spines more than a centimeter long. It was on this species that the problematical segmental organs were found, consisting of a pair of subtriangular, rounded, approximated, infundibuliform openings on either side of the median line between the legs and much smaller than the linear stigmata. *A. Brodiei* Scudd., Coalbrookdale, Eng. This species was considered at first by Westwood as the caterpillar of one of the Saturnidæ, a family of Lepidoptera; afterwards, by Woodward, as one of the Merostomata. Perhaps *Chonionotus lithanthracis* Jordan, from Saarbrück, belongs here.

Euphoberia Meek and Worth. Spines spinuliferous, but with a single-pointed tip, arranged in subdorsal and lateral rows; segments generally from two to three times broader than long. About a dozen species are known, mostly from Mazon Creek, Ill. Two species occur in England.

Amynilispes Scudd. Spines simple, arranged in dorsolateral rows; segments four times as broad as long. *Amynilispes Wortheni* Scudd., from Mazon Creek.

Eileticus Scudd. No spines, but large low tubercles, serially arranged; segments few, less than twice as broad as long. *Eileticus anthracinus* Scudd., from Mazon Creek.

3. Family **Archiulidæ** Scudder.

Dorsal plates closely consolidated, but still distinctly separable, though the anterior is rarely elevated much above the other. Body almost smooth or covered more or less abundantly with serially-disposed papillæ, from which in some cases hairs or small spines arise.

The members of this family resemble modern Diplopoda in their general appearance much more closely than either of the preceding families. The indications of spines or spinous hairs upon the sides of the body, the fusiform shape of the body, the length of the legs, and the indications in some of them of great breadth to the ventral plates present so many points of affinity to contemporaneous forms that they should be classed with the Archipolypoda. They are, however, still insufficiently known. Mostly occurring in America, they have also been found in Great Britain and on the continent of Europe.

Archiulus Scudd. Segments entire, of very variable size, but generally from two to three times broader than long, furnished with a few bristle-bearing papillæ. Four or five species are known to me from different parts of America, three coming from the sigillarian stumps of Nova Scotia. *Julus Brassi* Dohrn, from Lehbach, probably belongs here (or in the next genus), and perhaps also the three species of Julus named by Frič, from the Dyas of Bohemia. (*Palæojulus dyadicus* Gein., from the Dyas of Saxony, has been shown by Sterzel to be a fern, and Trichiulus, described by Scudder, from the American Carboniferous, also turns out to be a fern leaf.)

Xylobius Daws. Segments as in the preceding genus, but broken by longitudinal sutures into numerous quadrate frustra. Four species are known from the sigillarian stumps of Nova Scotia, besides two species (unpublished) from Mazon Creek and one from England.

4. Order **DIPLOPODA** Gervais.

Body elongated, usually cylindrical, of nearly uniform size, the head appendages borne upon a single apparent segment; each body segment composed of a single dorsal plate of great size, shorter below than above, corresponding to which there are two minute, narrow (rarely moderately broad) ventral plates, each bearing a pair of spiracles and of legs, excepting on the anterior segments, where there is only a single pair of legs to each dorsal segment; the legs are therefore inferior and approximate at base. No spines, but occasionally roughnesses and ridges or setæ on dorsal plates. Sexual organs situated anteriorly.

This family, by far the most abundant at the present day, was richer than the Chilopoda during Tertiary times, both in genera and species. Its earliest record is in the Cretaceous, a species figured by Heer, from Greenland, probably belonging here rather than in the Archipolypoda. Most of the Tertiary species are known only from amber.

Glomeridæ.—*Glomeris denticulata* Menge, from amber, is the only species known and is very briefly described.

Polydesmidæ.—Menge merely mentions the occurrence of two species of Polydesmus in amber.

Lysiopeltidæ.—Of this interesting family, Menge describes from amber six species of Craspedosoma, besides one figured by Koch and Berendt, and a distinct genus, Euzonus, with one species, *E. collulum*, also from amber, in which the body tapers considerably toward the head and at the tail; the antennæ are twice as long as the breadth of the head, with the first and seventh joints smallest and the third and fifth largest, the eyes consisting of twenty ocelli, set in a semicircle behind the antennæ.

Julidæ.—Koch and Berendt describe a single species of Julus from amber; Menge, in his notes to their work, describes briefly three others; Gravenhorst and others mention also the occurrence of a species of this genus in amber, and several species have also been found in Tertiary rocks. Thus Cotta refers to the living *Julus terrestris* a form found at Tharand, Saxony, concerning which it is questionable whether it be a fossil. Serres compares to the living *Julus sabulosus* a species found in the lacustrine limestones in the neighborhood of Montpellier. Hope mentions Julus as found in the marls of Aix, without further reference. But besides these, one species, (*J. antiquus* Heyden) has been described from the brown coal of Rott, and another (*J. telluster* Scudd.), from the Green River shales of Wyoming. Menge also briefly describes a species of Blaniulus from amber, and probably the *Julopsis cretacea* of Heer, from the Cretaceous deposits of Greenland, is to be referred to this family.

Polyxenidæ.—Polyxenus is represented by five species in amber, of which Koch and Berendt describe and figure two and the others are briefly characterized by Menge. Besides these, Menge describes an amber genus, Lophonotus,[1] in which the sixth antennal joint is the largest, the terminal joint very short and cylindrical, furnished above with four little teeth. A single species is known, *Phryssonotus hystrix* Menge sp.

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[1] This name had been used earlier for other insects, and may be replaced by Phryssonotus.

ARACHNIDA.

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CHARACTERISTICS AND GEOLOGICAL HISTORY.

The Arachnida are articulated animals in which the body is, as a rule, divided into two great masses, a cephalothorax and an abdomen. The cephalothorax is furnished with four pairs of articulated (normally, seven-jointed) legs, and in advance of them (1) a pair of jointed appendages or palpi which in some bear chelæ or other modified structures at the extremity and generally are looked upon as the homologues of some part of the jaws of insects; and (2) a pair of two-jointed mandibles or cheliceres, sometimes developed as a sucking organ, and considered by many as equivalent to the otherwise absent antennæ of true insects. The eyes are always simple and situated on the summit of the front portion of the cephalothorax. The abdomen is in some cases of a softer integument than the cephalothorax, in which its annulated character is disguised. It bears no legs, but sometimes has special jointed appendages either at the base, as in scorpions, or at the extremity, as in spiders. With slight exceptions arachnids undergo no metamorphosis after leaving the egg, the repeated sloughings of the integument being unaccompanied by structural changes.

The geological history of Arachnida, as known at the present time, presents some points of interest. Only a portion of the great groups into which the order is divisible are represented in the older rocks, and these, which are not confined to the lower types, attain a degree of perfection and a diversity of structure inconsistent with a belief in our having reached the primordial forms of this phylum in our retrograde search.

When, in 1858, Bronn published his prize essay on the distribution of fossils, only two species of Pretertiary Arachnida were known as such, one from the Carboniferous and one from the Jurassic formation, and the knowledge of Tertiary forms was confined entirely to the then recently published work of Koch and Berendt on the species from amber. Since then Menge has increased somewhat our knowledge of the amber fauna, and it includes to-day nine-tenths or more of the known Tertiary species. But it is only within the last fifteen years that our knowledge of Pretertiary Arachnida has been extended beyond the description of two or three species. The number is still exceedingly few — between 20 and 30 species — but it is being constantly extended, and the abundance of Arthropoda brought to light in recent years in the Carboniferous deposits of Allier, Bohemia, Scotland, and Illinois, leads us to expect an early and considerable extension of the list. This expectation is strengthened by Lindström's, Hunter's, and Whitfield's discoveries of scorpions in the Upper Silurian rocks of Gotland, Scotland, and New York.

The forms that have been found fossil in the earlier formations prove, as might be expected, to belong mostly to those having a dense integument, and in the two species believed to be true Araneæ the abdomen was probably provided with more or less densely chitinous dorsal plates. With these two exceptions and a single genus of Pedipalpi, all the Paleozoic Arachnida (only a single Mesozoic form is known) belong either to the Scorpiones or to a peculiar group, the Anthracomarti. This group is not found later, and the single known species of Mesozoic Arachnida[1] is a true Aranea. The paucity of remains of Arachnida in Mesozoic strata is somewhat remarkable. Besides the species mentioned above, only one other has been indicated, a species supposed to belong to the Araneæ, from the English Lias.

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[1] Palpipes or Phalangites, believed even by Thorell to be an arachnid, has been shown by Seebach to be a stomatopodous crustacean.

Thanks to the amber deposits of Prussia, we know far more about the Tertiary history of Arachnida than would be possible if our sole reliance were on the rocks, the latter furnishing us with only about double the number of those occurring in Pretertiary deposits. In the amber alone occur all the suborders of Arachnida (excepting the Pedipalpi and the already extinct Anthracomarti), as well as all the families of Araneæ, excepting one peculiar to the Jura; but in the Tertiary rocks neither Chelonethi, Scorpiones, nor Opiliones has been recognized; of the Pedipalpi, a single species is referred to by Serres from the marls of Aix, but too obscurely to take account of it.

Examining the Araneæ alone, which are far better represented in the Tertiaries than are the other suborders, we find a very large number of extinct genera. In all, 71 are now known, 66 from Europe and 13 from America, 8 being common to both. Of these 37 are accounted extinct (35 from Europe and 2 from America), and none of these have been found on both continents.

In the stratified Tertiary deposits the same families of Araneæ are in every instance found in both Europe and America, excepting the Dysderides, which family has a single representative in America and none in Europe. It also appears that just those families which are represented abundantly in amber are also found to some extent in the American Tertiary fauna and (excepting, as before, the Dysderides) in the European rocks.

It is only in the rocks of the temperate regions of Europe and North America that any Arachnida have been found in a fossil state, and these, so far as the indications have any meaning, invariably point, whether in Carboniferous or in Tertiary deposits, to a warmer climate than now obtains in the localities where they occur. This becomes more marked when we reach the Tertiary rocks and can compare the types more closely with existing forms, a number of the genera to which, for instance, the amber spiders belong being now exclusively tropical.

The following table gives a general systematic view of the distribution of Arachnida in the different geological formations since their first appearance in the Upper Silurian.

Geological distribution of Arachnida.[1]

Groups.	Paleozoic.				Mesozoic.				Cenozoic.				Modern period.
									Oligocene.				
	Silurian.	Devonian.	Carboniferous.	Dyas.	Trias.	Lias.	Jura.	Cretaceous.	Europe.	America.	Miocene.	Pliocene.	
Acari	....	....	....	....	....	....	....	....	33	1	2	....	....
Chelonethi	....	....	....	....	....	....	....	....	9	....	....	....	....
Arthracomarti	....	....	16										0
Pedipalpi	....	....	2	....	....	....	....	....	....	....	....	....	....
Scorpiones	3	....	8	....	....	....	....	....	1	....	....	....	....
Opiliones	....	....	....	....	....	....	....	....	18	....	....	....	....
Araneæ:													
Saltigradæ	....	....	....	....	....	....	....	....	15	3	....	....	....
Citigradæ	....	....	....	....	....	....	....	....	1	....	....	....	....
Laterigradæ	....	....	....	....	....	....	....	....	22	8	4	....	....
Territelariæ	....	....	2	....	....	....	....	....	1	....	....	....	....
Tubitelariæ	....	....	....	....	....	....	1	....	72	8	3	....	....
Retitelariæ	....	....	....	....	....	....	....	....	54	8	5	....	....
Orbitelariæ	....	....	....	....	....	....	....	....	17	12	3	....	....

[1] The figures represent the number of species.

1. Order ACARI Leach.

Body compact, robust, the cephalothorax and unsegmented abdomen being united in one mass. Mouth-parts usually produced into the form of a rostrum.

All the principal families are represented in the Tertiaries, our knowledge of them coming mainly from amber. With a single exception, they have all been referred to existing genera. None have been reported from older rocks.

Sarcoptidæ.—A species of Acarus has been found in amber and one is referred to by Heer as occurring at Oeningen.

Oribatidæ.—A species of Oribates and four of Nothrus occur in amber.

Ixodidæ.—A single species of tick found in the Green River beds of Wyoming is probably to be referred to this group.

Gamasidæ.—One species of Sejus is figured by Koch and Berendt from amber.

Hydrachnidæ.—Heyden figures a species of Limnochares from the brown coal of Rott.

Bdellidæ.—As we reach the higher Acari their fossil representatives become more numerous. Four species of Bdella and one of Cheyletus have been found in amber.

Trombididæ.—This family of Acari is by far the best represented in a fossil state, more than twice as many species having been recovered from amber as all the other families together have furnished, but none have been found in the stratified rocks. Five species of Trombidium, eight of Rhyncholophus, three of Actineda, four of Erythæus, two of Tetranychus, and one of Penthaleus have been described and in part figured by Menge and Koch, besides one of the only genus not now living, Arytæna Menge, having the aspect of a Trogulus.

2. Order **CHELONETHI** Thorell (Pseudoscorpiones Latreille).

Body strongly depressed, the sides of the body showing no division between cephalothorax and abdomen, the latter composed of ten or eleven segments. Palpi long and stoutly chelate.

Hope catalogues a species of Chelifer from the Tertiary deposits of Aix, but the only forms which have been described are those from amber, which have been carefully studied by Menge and figured in his paper on Chernetidæ. He finds five species of Chelifer and one each of Chernes, Cheiridium, and Chthonius, all of the genera still existing. Some of the species, however, differ so much from living forms that Menge previously endeavored to establish two distinct genera for them. A species of Carboniferous arachnid, long supposed to belong in this group, has recently been shown by Fritsch to be an immature and imperfect scorpion. (See, also, page 95.)

3. Order **ANTHRACOMARTI** Karsch.

Body somewhat depressed, the cephalothorax and abdomen distinctly separable. Cephalothorax usually made up in large part of more or less wedge-shaped pedigerous segments, the arrangement of which corresponds to that of the coxæ. Abdomen forming a single mass and composed of from four to nine distinct joints. Palpi not much longer than the legs and simply terminated.

This group, the only extinct order of Arachnida, was established by Karsch for some interesting Carboniferous forms of somewhat obscure relations allied to the Phrynidæ and Phalangidæ, but very distinct from either of them. Their position seems to be between the Chelonethi and the Pedipalpi, to the latter of which they bear perhaps the closest relations. The Anthracomarti were the most varied in structure and, with the possible exception of the scorpions, the most abundant in species of the Carboniferous Arachnida, and being unknown after that period they may be considered the most characteristic of Paleozoic Arachnida. The forms hitherto known may be grouped in four families.

1. Family **Arthrolycosidæ** Harger.

Cephalothorax orbicular. Coxæ radiating from a central pit. Abdomen oval, narrower at base than the cephalothorax, with no longitudinal sculpturing, and smooth. Segments seven in number, undoubtedly all visible below. No abdominal appendages.

Arthrolycosa Harg. Cephalothorax twice as large as the abdomen. Founded upon *A. antiqua* Harger, from the Carboniferous iron-stone nodules of Mazon Creek, Ill.

Rakovnicia Kušt. Cephalothorax smaller than the abdomen. *R. antiqua* Kušta from the coal measures of Bohemia.

2. Family **Poliocheridæ** Scudder.

Cephalothorax quadrate, not much smaller than the abdomen. Coxæ radiating apparently from a median line. Abdomen rounded, of equal breadth with the cephalothorax, composed of only four segments, of which the basal is very short and the others of equal length. No abdominal appendages.

Poliochera Scudd. One species, *P. punctulata* Scudder, from Mazon Creek, Ill.

3. Family **Architarboidæ** Karsch.

Cephalothorax variable in form, at least half as large as the abdomen; coxæ radiating from a central pit, a median line, or from a broad triangular space, its base on the abdominal margin. Abdomen orbicular or oval, broad at base, with a lateral ridge on each side converging toward the anus; the surface moderately smooth; segments seven to nine in number, visible below, though the basal ones often extremely shortened in the middle. No abdominal appendages.

Geraphrynus Scudd. Cephalothorax fusiform, angulate in front, nearly as large as the abdomen; the coxæ radiating from a median line. Sides of the body scarcely showing any constriction between the cephalothorax and the abdomen. Abdomen subfusiform, composed of nine segments, with a large basal, triangular, post-thoracic plate crowding the middle of the shorter basal segments out of place on the dorsal surface. *G. carbonarius* Scudd., from the Carboniferous nodules of Mazon Creek, Ill.

Architarbus Scudd. Cephalothorax orbicular, broadly rounded in front, much smaller than the abdomen; the coxæ radiating from a central pit. Sides of the body scarcely showing any constriction between the cephalothorax and the abdomen; the latter oval, composed of nine segments, of which those on the basal half are very much shorter than the others. *A. subovalis* Woodw., from the Coal Measures of Lancashire, Eng., has the piece exposed between the posterior coxæ more than twice as broad as long. (Probably *Curculioides Ansticii* Buckl. belongs here.) In *A. rotundatus* Scudd., from Mazon Creek, Ill., this piece is triangular, of equal length and breadth, the post-thoracic plate large, greatly distorting the basal segments of the abdomen. Roemer mentions a third species (*A. silesiacus*), from the Carboniferous deposits of Glatz.

Anthracomartus Karsch. Cephalothorax quadrate, the front square, or scarcely convex, about half the size of the abdomen; the coxæ laterally affixed, radiating from a broad triangular sternal plate, the base of which forms the posterior margin. Sides of the body showing a distinct though slight constriction between the cephalothorax and the abdomen by the more convex sides of the latter. Abdomen orbicular, a little longer than broad, composed of seven segments of similar length. Four European species are known, from the Carboniferous deposits of Silesia and Bohemia, and two American, from those of Illinois. (Probably *Termes Hageni* Gold. (Palæontogr., Band IV., Pl. 6., Fig. 8) and *Libellula carbonaria* Scudd. (Proc. Amer. Assoc., Vol. XXIV, B. 110, Fig. 1), both represented by imperfect bodies only, belong in this neighborhood.)

4. Family **Eophrynoidæ** Karsch.

Cephalothorax quadrate or triangular, less than one-third the size of the abdomen, broken dorsally into many distinct plates. Coxæ radiating from a sunken median furrow. Abdomen ovate or orbicular, much broader than the cephalothorax, and separated from it by a distinct lateral constriction, composed of nine or ten segments, of which the penultimate and antepenultimate bear lateral terminal spines.

Kreischeria Gein. Cephalothorax subquadrate, narrowing strongly in front, the dorsal surface with three large median plates, one in front and two behind, and on each side three smaller lateral plates. Dorsum of abdomen broken by oblique sutures into a median and a lateral field. ***Kreischeria Weidei*** Gein., from the Coal Measures of Zwickau, Saxony, is a gigantic species, and the largest known fossil arachnid, excepting some scorpions.

Eophrynus Woodw. Cephalothorax triangular, pointed in front, its dorsal surface tumid, completely broken into great tuberculate bosses arranged in a lateral row down either side and a median row separating into two at the posterior margin. Dorsal surface of abdomen tuberculate, with two lateral rows of large rounded tubercles and a median row of large stellate tubercles. The genus was founded on ***E. Prestvicii***, from the iron-stone nodules of the Coalbrookdale and Dudley Coal Measures in England. This species was formerly taken by Buckland for a beetle, and was figured by him in his Geology and Mineralogy as *Curculioides Prestvicii*. Since then Stur has described a second species from Ostrau, in Moravia, under the name of *E. Salmi*.

4. Order **PEDIPALPI** Latreille.

Body depressed, the cephalothorax and abdomen distinctly separate. Cephalothorax compact, but sometimes broken into two parts; the legs, especially the front pair, very long. Abdomen composed of an abdomen proper of more than seven joints, to which is generally appended a post-abdomen, formed of a few small joints followed by a generally articulated seta. Palpi highly developed, spinous, apically chelate.

Serres mentions a species of Phrynus from the Tertiary deposits of Aix, excepting which the only known fossil is a Thelyphonus-like arachnid from the Carboniferous deposits of Bohemia and America, belonging to a family distinct from those now existing.

Family **Geralinuridæ** Scudder.

Cephalothorax divided into two masses: the hinder much the smaller, short, and transverse, and carrying only the hindmost legs; the front portion large, tapering anteriorly, and furnished with long and slender cheliceres. Abdomen subfusiform. While most nearly related to the Thelyphonidæ, this family, by the division of the cephalothorax, shows more affinity to the Nyctalopidæ.

Geralinura Scudd. Cephalothorax ovate, the front rounded, one-third as broad as hinder portion. Palpi large and robust, with interior spines. First two pairs of legs slender, the hinder stout and broad. Abdomen composed of nine joints, the basal three rather short, the others subequal and longer; post-abdomen much as in Thelyphonus. *G. carbonaria* Scudd., in iron-stone nodules from Mazon Creek; *G. bohemica* Kušt. sp., from Rakonitz, Bohemia.

5. Order **SCORPIONES** Thorell.

Body depressed; the cephalothorax and abdomen distinctly separated, as in the last group; the latter composed (1) of seven joints, forming the abdomen proper, at the base of which beneath is a pair of pectinate appendages, and (2) of six slender joints, forming the tail or post-abdomen, of which the last joint is vesicular and developed as a sting. Palpi large and chelate.

This is, perhaps, the most sharply defined of all the orders of Arachnida, and is a group of the greatest antiquity, several species having been found in the Upper Silurian rocks of Sweden, Scotland, and New York, while the Carboniferous beds have yielded a considerable variety of forms in both the Old and New World, all of which seem, at least as far as any characteristics have been noted, to enter as completely into the order as if they were living to-day. The Paleozoic forms represent, however, a distinct and extinct suborder, in which those from the European Silurian beds are to be distinguished as a separate group from the Carboniferous types, among the latter of which, however, the single known American scorpion must be placed. The Silurian species are very recent discoveries, the characteristics of which have been made known to us by Thorell, Peach, and Whitfield.

1. Suborder ANTHRACOSCORPII Thorell.

Anterior margin of cephalothorax generally produced centrally. Dorsal eye tubercle situated not far from or at the anterior margin, in front of or between the lateral eyes; the dorsal eyes when present generally rather large. Bases of the second pair of legs separated from each other by a pair of median plates. Rachis of comb formed of four or more plates.

This suborder includes all and only the Paleozoic forms and contains two families, the first embracing the species from the European Silurian, the second the American Silurian scorpion and the Carboniferous species of both continents.

1. Family **Palæophonoidæ** Thorell.

Anterior margin of cephalothorax very broadly emarginate. Eye tubercle small, situated mesially, near but not on the front margin of the cephalothorax. Sternum large and pentagonal, bounded anteriorly by the third pair of coxæ. Movable finger of mandibles apparently armed with a single row of teeth. Hands stout. Legs short, gradually tapering; the tibial and femoral joints scarcely longer than broad; the last tarsal joint conical, pointed, without claws or with a single minute apical claw.

This group contains the single genus Palæophonus, if the species almost simultaneously discovered in the Ludlow beds of Gotland and Scotland in the summer of 1884 are, as is probably the case, not generically distinct. It is remarkable for the tapering form of the legs. The Gotland specimen, *Palæophonus nuncius* Thorell and Lindström, has been carefully studied by Thorell, and is certainly remarkable for the excessively heavy joints of the palpi before the chelate tip, as well as for the brevity of the legs and their form, since all of them are stout and the last three joints taper regularly to a single, pointed, spine-like claw. Only a preliminary notice of the Scottish species has yet been given by Peach, according to whom the sternum shows a large pentagonal plate, against which the wedge-shaped coxæ of the last pair of legs abut, while the coxæ of the third pair bound the pentagonal plate along its upper margins and meet in the mid-line of the body, where they are firmly united.

2. Family **Eoscorpioidæ** Scudder.

Anterior margin of cephalothorax roundly or angularly produced in the middle. Sternum compound, bounded anteriorly by the second pair of coxæ. Hands slender. Legs comparatively long, of nearly uniform breadth; the tibial and femoral joints much longer than broad; the last tarsal joint cylindrical, blunt at tip, and armed with a pair of claws.

1. Subfamily *Proscorpionini* Scudder.

Dorsal eye tubercle of moderate size, situated mesially on the front margin of the cephalothorax; the dorsal eyes small; lateral eyes in two rows on antero-lateral border.

Here belongs the single species *Proscorpius Osborni* Whitfield, from the Silurian (extreme base of Helderberg group) of New York, discovered in the winter of 1882, but only just made known; the horizon from which it comes is probably somewhat lower than that at which Palæophonus has been found, but the species agree more closely with the later Carboniferous types.

2. Subfamily *Eoscorpionini* Scudder.

Dorsal eye tubercle small, situated mesially near but not on the front margin of the cephalothorax; the dorsal eyes minute; lateral eyes in two rows on antero-lateral border. Rachis of combs composed of numerous lamellæ.

Eoscorpius Meek and Worth. No intermediate lamellæ in the combs. Two species in the Carboniferous beds of Illinois. Mazonia Meek and Worth. is probably synonymous.

Centromachus Thorell. Combs provided with numerous intermediate lamellæ. Five species from the Carboniferous beds of Scotland and England.

3. Subfamily *Cyclophthalmini* Thorell.

Dorsal eye tubercle very large, occupying nearly half the cephalothorax centrally in front; the dorsal eyes very large; lateral eyes forming a semicircular row behind and beside the latter. Rachis of the combs formed of few plates; no intermediate lamellæ.

Cyclophthalmus Corda. Three species from the Carboniferous of Bohemia.

Other species of this family are indicated from Bohemia, Illinois, and Nova Scotia. The problematical genus Glyptoscorpius Peach is referred by him to the Eurypteridæ.

2. Suborder NEOSCORPII Thorell.

Anterior margin of cephalothorax truncate or emarginate in the middle. Dorsal eye tubercle generally far removed from the anterior margin, behind the lateral eyes; the dorsal eyes themselves, when present, comparatively small. Sternum bounded anteriorly by the coxæ of the second pair of legs; bases of these legs attingent at the middle line. Rachis of combs formed of no more than three plates.

3. Family **Buthoidæ** Simon.

Sternum narrowing forward, subtriangular. Intermediate lamellæ of the pectoral combs rather few in number, most of them angular and larger than the fulcra, and forming only one series. Three principal lateral eyes and 2–0 accessory eyes on each side of the cephalothorax. *Tityus eogenus* Menge, from amber, is the only Tertiary species tolerably known.

6. Order **OPILIONES** Sundevall.

Body compact, depressed; the cephalothorax and abdomen united in a single mass, the latter composed probably of eight segments, of which the five basal joints are so obscurely marked as to form apparently a single mass. Palpi filiform, apically achelate. Legs long, terminated by a single claw.

This order is represented only in Cenozoic times and is indeed known in a fossil state only in amber. Most of the species belong to the family *Phalangioidæ*, which is represented by a single species each, of the genera Acantholophus, Phalangium, Liobunum, Platybunus, and Cheiromachus, and by three which have been referred to Opilio. The *Nemastomoidæ* are represented by the genus Nemastoma (1 sp.), and the *Gonyleptidæ* by Gonyleptes (1 sp.).

7. Order **ARANEÆ** Sundevall.

Body robust, composed of two well-separated masses; the abdomen being petiolated with, at the most, but faint marks of segmentation and furnished apically with spinnerets. Palpi subfiliform, simple, excepting that the last joint of the male possesses peculiar organs subservient to copulation, never chelate.

1. Suborder SALTIGRADÆ Latreille.

A dozen species of *Attoidæ* are known from amber, belonging to the genera Propetes and Gorgopis, besides species of Steneattus and Euophrys. In addition to these we have three species of Parattus from the Tertiary beds of Colorado, an extinct genus interesting from its affinity to Gorgopis, and the excellently preserved *Attoides eresiformis* from the gypsum of Aix. Of the *Eresoidæ*, two species of Eresus are found in amber.

2. Suborder CITIGRADÆ Latreille.

Represented by the *Lycosoidæ*, in which Menge has founded the genus Linoptes on a single amber species.

3. Suborder LATERIGRADÆ Latreille.

Koch establishes the family *Archæoidæ* upon the single amber genus Archæa, with half a dozen species, remarkable for the globular elevation of the cephalic portion of the cephalothorax, the long mandibles, and the unusually small and slender palpi. He believed that it differed totally from all other spiders, but both Menge and Thorell refer it to the position here assigned. The *Thomisinæ* are richly represented in the

Tertiaries, especially in amber, ten genera being known, of which Clythia and Syphax, with five species each, and one or two others are known only from amber. The species from the rocks have all been referred to Thomisus and Xysticus, existing genera, and have been found at Oeningen, Rott, and Florissant (Colo.).

4. Suborder TERRITELARIÆ Thorell.

Clestes, an extinct genus of *Theraphosoidæ*, is represented by a single species in amber; but the most important fact is that Thorell refers to the existing family *Liphistioidæ* that interesting Carboniferous form from Silesia described under the name of *Protolycosa anthracophila*, on account of the brevity of the first pair of legs and the density and segmentation of the dorsal integument of the abdomen. Thorell also calls attention to the unusually short second joint of the palpi and to the spines on the abdomen as points which might justify the establishment of a distinct family for it. Though less well preserved, Fritsch's *Palaranea borassifolia*, from the Coal Measures of Bohemia, would seem to fall in this same group. No other Carboniferous Araneæ are known in this group, and no Mesozoic or Tertiary species are known, though a single genus exists at the present day in the East Indies.

5. Suborder TUBITELARIÆ Thorell.

The families which are represented in the Tertiary deposits of Europe and America are the ones most abundant in the present epoch, and the suborder itself includes more than a third of the Tertiary Araneæ. The fossil *Dysderides* of Europe (16 species) are all from amber and include eight species of Segestria, into which the single species from the volcanic strata of Colorado also falls. Therea is an extinct genus peculiar to amber. The *Drassides* are very abundant in the European amber, and the American fauna shows four species of Clubiona and one of Aryphæna, both living genera represented in amber, with Clubiona (which has no less than eight amber species) also at Oeningen; but besides these there are half a dozen extinct genera found in amber, mostly with only one or two species each. Six genera of *Agalenidæ* are found in the European Tertiaries, half of them in amber, the other half at Rott and Oeningen. The amber genera are all extant, but one of the species from Rott—*Argyroncta antiqua* Heyd.—belongs, according to Thorell, to an extinct type (Elvina), in which the palpi are evidently thicker than the legs. Bertkau, however, who has since studied it carefully, retains it in Argyroneta. Two species from Colorado belong to Titanœca, a European genus, not found fossil in the Old World, but allied to Amaurobius, one of the genera represented by three species in amber. Besides these, Hasseltides, a Mesozoic genus from Solenhofen, is referred to this family by Weyenbergh. The *Hersilioidæ* are represented in amber by two species of Hersilia, a subtropical genus, not now existing in Europe, and a species of Gerdia, a remarkable generic form peculiar to amber, in which the head is raised to a high vertical boss, the tarsi are two-jointed, and the spinnerets are very long and three-jointed. And, finally, Thorell establishes a new family *Mizalioidæ* for the curious genus Mizalia, of which four species are known in amber, in which the cephalothorax is produced like a blunt snout in front of the eyes, the legs and palpi are stout, and the intermediate spinnerets are more than double the length of the inferior.

6. Suborder RETITELARIÆ Thorell.

Next to the Tubitelariæ in importance, especially so far as the amber fauna is concerned, comes this suborder. The *Scytodoidæ* contain a species of Pholcus and another of the extinct genus Phalangopus, but the mass of this group belong to the *Theridioidæ*, a family more abundant than any other among the Araneæ in Tertiary deposits, more than a fourth of the European species belonging here, with fourteen genera. America, whose stratified deposits are generally richer than the similar beds of Europe, is in this instance poorer, but possesses a single species of Linyphia and two of Theridium, besides some egg-cocoons apparently made by a spider of this group. Theridium is one of the very richest of the amber genera, having sixteen species, while three others are described from Oeningen and Aix. Linyphia has three species in amber and two at Rott; Erigone, one each in amber and at Rott. Schellenbergia is an extinct genus founded by Heer for a spider found at Oeningen. Among the more prolific genera found in amber, and not named above, are Ero, with seven species; Walckenaeria and Zilla, with five each; and Thyelia, a form peculiar to amber, with no less than ten species. Other extinct genera are Flegia, Corynitis, Anandrus, Clya, and probably Dielacata, most of which are known by a single species each.

7. Suborder ORBITELARIÆ Perty.

In this group, containing the single family *Epeiroidæ*, there is a curious disparity of representation between the European and the American Tertiaries, 8 per cent. of the European Tertiary spiders belonging to this group, while no less than 44 per cent. of the American species fall here, and no other group shows in America so many novelties. Among these are single species of the genera Nephila and Tetragnatha, not found fossil in Europe, and four species of an extinct type, Tethnæus, a genus of spiders of compact form, with short and stout legs, of not very unequal length, and in which the two front pairs are unusually heavy. They all come from the beds at Florissant, Colo. Six species referred to Epeira also come from Colorado, two from Rott, one from Oeningen, and two from amber. All the other Tertiary Epeiroidæ come from amber and include two or more species each of Græa, Antopia, Siga, and Androgeus, all extinct types, besides a few others.

INSECTA.

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(See, also, pp. 36, 46, 51, 58, 65, 85, 94, and 96.)

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CHARACTERISTICS AND DEVELOPMENT.

Hexapods, or true insects, are articulated animals in which the body of the adult is divided typically into three principal regions: head, thorax, and abdomen. The head is composed of several consolidated segments (generally looked upon as four in number) and bears above a pair of antennæ, serving as sense and tactile organs, and below three pairs of jointed appendages, serving under various modifications as mouth-parts. These are designated from the front backward as mandibles, maxillæ, and labium. The opposing basal parts of the last are more or less closely united to form a lower lip, and upon the opposite front or upper side of the mouth a hinged and undivided, though sometimes partially cleft, plate is found, called the labrum or upper lip; the maxillæ and labium may have jointed appendages or prolongations, the modifications of which, profoundly affecting the modes of life and nourishment of insects, characterize the different primary groups and are undoubtedly of great antiquity. A pair of compound eyes is found on the sides of the head and ocelli are sometimes added in front.

The thorax is composed of three segments, each of which bears a pair of legs and each of the hinder two a pair of wings, which, especially the posterior, are occasionally aborted. Each of these segments is again divided by sutures into several plates, bearing definite and similar relations on each segment; they are situated above, on the sides, and below, and are distinguished respectively as nota, pleura, and sterna, the pleura being again subdivided into an anterior episternal and a posterior epimeral piece. Between nota and pleura the wings;

and between pleura and sterna the legs, are inserted. The latter consist of five parts: coxa, trochanter, femur, tibia, and tarsus, the last rarely simple, generally five-jointed, the final joint armed with a pair of claws and sometimes with fleshy pads or lobes.

The wings, the most characteristic feature of the class, are composed of a thin membrane, stretched, like a flattened bladder, upon a framework of veins, the arrangement and disposition of which are definite and of the utmost importance for paleontology, as these are the parts, particularly in the older insects, which are more often preserved, and frequently serve as the sole clew to relationship. These veins or nervures are hollow, ramificating, and more or less anastomosing tubes, containing tracheæ and the fluids of the body. The principal veins are six in number, arising in sets of three, from two distinct roots, the marginal, mediastinal, and scapular veins being articulated anteriorly, the externomedian, internomedian, and internal veins posteriorly; by a basal bend in the course, however, the scapular or the externomedian vein may, as it were, select its articulation at will. The definite arrangement of these veins and their off-shoots has frequently served, in all orders of insects, as a base for generic, and occasionally for family, distinctions, but its wider use has been much hampered by a very variable nomenclature of the veins in different orders, which has taken no note of their homologies.

The different orders differ also in the general texture of the front wings and their relative size, as compared to the hind wings, the former being sometimes of a much denser consistency than the latter and serving as a protective covering to them, which then become the principal organs of flight, and are often folded in various ways for concealment beneath the front wings.

The abdomen is generally composed of nine or ten segments, to each of the last two or three of which one, two, or even three pairs of appendages may be attached, often closely connected with the reproductive function as ovipositors or clasping organs, but also as stings and jointed filaments. In ovipositors and stings the appendages of opposite sides or of different segments, or of both, are often combined to form compound structures; in the other cases the appendages are usually simple and distinct.

Respiration is effected by means of tracheæ filled with air through lateral openings or stigmata on the sides of most of the thoracic and abdominal segments, to the number usually of nine or ten on each side of the body; these are connected by main trunks extending along each side of the body and themselves divide into numerous ramifications, which permit the aëration of every part of the body.

Growth is secured through repeated sloughings of the chitinous integument of the body, accompanied by very varied and remarkable metamorphoses. In some types the young as hatched from the egg very closely resemble the parent insect, except in the absence of wings, and when the parent is itself apterous the resemblance is still more evident, In others, on the contrary, the difference is very important, and to bridge over the wide distinction a quiescent period intervenes between the initial and the final period, resulting in a threefold life condition, the first stage being known as the larva, caterpillar, or maggot, the second as the pupa or chrysalis, and the final as the imago or perfect stage. Such a metamorphosis is designated as complete. The insects with incomplete metamorphosis, on the other hand, do not need such a quiescent stage, the ordinary ecdysis sufficing for all the changes required for the assumption of maturity.

As the conditions under which insects are preserved in the rocks do not admit of any study of their internal structure, this side of their organization need not here be touched upon. Yet it is remarkable to find how perfectly external parts and organs of the utmost delicacy have been preserved not only in amber, which has revealed and is yet to reveal the most important and exact data regarding insect life in the early Tertiaries, but even in the rocks themselves, where the most delicate hairs, antennal outgrowths, the appendages of the feet, and the microscopic facets of the compound eye are exactly preserved. Especially is this true of the neuration of the wings in every type and in all time, thus preserving for us the most precious data for the rehabilitation of the insect life of different epochs.

As the classification here followed is intimately connected with the historical development of the different ordinal types, its exposition is postponed to the close, where the subject will be discussed in connection with the geological distribution of insects.

A.—PALÆODICTYOPTERA Goldenberg.

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Body generally elongated, mouth-parts variously developed; antennæ filiform. Thoracic joints subequally developed; legs moderately long. Mesothoracic and metathoracic wings closely similar, equally membranous; the six principal veins always developed, the marginal simple and forming the costal border, the mediastinal generally simple or with superior branches only; the other veins usually dichotomize; stout and well-defined cross-veins rare; membrane generally reticulate. Wings in repose lying on the abdomen, the anal area of the hind wings, though usually of great distal extension, never plaited, though sometimes broadly folded. Abdomen usually long and slender, the last joint often furnished with simple articulated appendages.

The insects composing this order were in fact ordinally undifferentiated Hexapoda, and comprised all the insects of Paleozoic time, together with a few later ones. They may be divided by their general facies and by their evident relationship to succeeding types into four sections, Orthopteroidea, Neuropteroidea, Hemipteroidea, and Coleopteroidea.

1. Section **ORTHOPTEROIDEA** Scudder.

1. Family **Palæoblattariæ** Scudder.

Ancient cockroaches in which the externomedian vein of the front wing is completely developed, dividing in the outer half of the wing, its branches generally occupying the apical margin; anal branches terminating on the inner margin of the wing.

1. Subfamily *Mylacridæ* Scudder.

Branches of the mediastinal vein arranged in a radiate manner, mostly springing from a common point at the base of the wing; mediastinal area subtriangular, uniformly tapering apically. (North America.)

Mylacris Scudd. Wings broad. Mediastinal and scapular areas together occupying less than half the wing. Scapular area larger than the mediastinal. Carboniferous, ten species. Cape Breton, Nova Scotia; Pennsylvania; Illinois.

Promylacris Scudd. Body much arched. Wings broad. Mediastinal and scapular areas together not occupying more than a third of the wing. Scapular area smaller than the mediastinal, the scapular running obliquely to the costal margin. Carboniferous. *P. ovale* Scudd. Mazon Creek, Ill.

Paromylacris Scudd. Body much arched. Pronotal shield more than twice as broad as long. Wings extremely broad. Mediastinal area large and extended and, with the scapular vein, occupying half the wing. Externomedian area expanding apically. Carboniferous. *P. rotundum* Scudd. Mazon Creek, Ill.

Lithomylacris Scudd. Wings slender. Mediastinal and scapular areas together occupying more than half the wing; externomedian area small and compressed, scarcely expanding apically. Carboniferous. Four species. Pennsylvania and Illinois.

Necymylacris Scudd. Some of the apical branches of the mediastinal vein arising beyond the base of the wing and scarcely partaking of the radiate arrangement of the others. Carboniferous. Two species. Pennsylvania.

2. Subfamily *Blattinariæ* Scudder.

Branches of the mediastinal vein arising at regular intervals from a principal stem; mediastinal area generally band-shaped. (Europe and North America.)

Etoblattina Scudd. Mediastinal area comparatively short; scapular vein not reaching tip of wing and, with the externomedian, which is comparatively large, occupying less than half the wing; internomedian vein comparatively long. Carboniferous and Trias. About 25 species. Europe and North America.

Spiloblattina Scudd. Mediastinal area comparatively short; scapular area just reaching the tip of the wing and, with the externomedian, occupying about half its area; externomedian and internomedian veins diverging around a median stigma. Trias. Four species. Colorado.

Archimylacris Scudd. Mediastinal area comparatively short; scapular terminating below the tip and, with the externomedian, which is comparatively small, occupying less than half the wing; internomedian vein comparatively long. Carboniferous. Three species. Nova Scotia, Pennsylvania, and Illinois.

Anthracoblattina Scudd. Mediastinal area comparatively long; scapular and externomedian areas together occupying less than half the wing; the branches of the former superior, of the latter inferior; internomedian vein comparatively long. Carboniferous. Twelve species. European.

Gerablattina Scudd. Mediastinal area comparatively long; scapular and externomedian areas together occupying less than half the wing, the branches of both superior; internomedian vein comparatively long. Carboniferous. Thirteen species. Europe and North America.

Hermatoblattina Scudd. Mediastinal area comparatively long; scapular and externomedian areas together occupying less than half the wing, the branches of the former inferior; internomedian vein comparatively long. Carboniferous. Two species. Germany.

Progonoblattina Scudd. Principal veins closely crowded in the basal half of the wing; scapular area not reaching apex, but with the externomedian area occupying more than half the wing, the branches of the latter inferior; internomedian vein comparatively short. Carboniferous. Two species. Germany and Switzerland.

Oryctoblattina Scudd. Principal veins widely separated at base: scapular area surpassing apex and, with externomedian, occupying more than half the wing, the branches of latter inferior; internomedian vein comparatively short. Carboniferous. Three species. Germany and Illinois.

Petrablattina Scudd. Scapular and externomedian areas together covering more than half the wing, the externomedian vein directed toward and terminating near the middle of the inner border of the wing, its branches superior; internomedian vein very short. Carboniferous and Trias. Four species. Germany, Nova Scotia, and Colorado.

Poroblattina Scudd. Scapular and externomedian areas together covering more than half the wing; the externomedian vein directed toward the outer half of lower border, its branches superior; internomedian vein moderately long. Trias. Two species. Colorado.

2. Family **Protophasmida** Brongniart.

Ancient walking-sticks, in which the front wings were diaphanous and as fully developed as the hind wings and both were similar in form and general neuration to those of other Palæodictyoptera, being long and usually slender, with very simple branched veins.

Titanophasma Brongn. Wings very large, moderately slender; the neuration moderately abundant; scapular vein beginning to branch in the middle of the basal half of the wing. Carboniferous. Three species. Commentry, France; Saarbrück basin; Pittston, Pa.

Litoneura Scudd. Wings of moderate size, the veins comparatively few, distant, and simple; scapular vein first branching beyond the middle of the wing and usually far from the first forking of the externomedian vein, its branches arising from the main stem. Carboniferous. Three species. Saarbrück basin.

Dictyoneura Goldenb. Wings of rather small size, with sparse neuration, the scapular nervules springing from a principal branch, which arises before, generally far before, the middle of the wing, the nervules only at some distance beyond the same; internomedian vein simple. Carboniferous. Four species. Saarbrück basin.

Polioptenus Scudd. Wings similar to the last, the principal scapular branch arising only just before the middle; internomedian vein branched. Carboniferous. *P. elegans* Goldenb. sp. Saarbrück basin.

Archæoptilus Scudd. Wings of huge size, the neuration tolerably abundant, the main scapular branch arising about the middle of the wing and having numerous off shoots; externomedian vein branching abundantly in the middle of the wing. Carboniferous. *A. ingens* Scudd. England.

Protophasma Brongn. Wings of large size; scapular nervure simple; neuration rather open except in the anal area, where it is made up of very crowded parallel veins mostly forked. Carboniferous. *P. Dumasi* Brongn. Commentry, France.

Breyeria Borre. Wings of moderate size, triangular, much broader next the base than beyond, the tip roundly pointed; scapular vein simple; neuration sparse. Carboniferous. *B. borinensis* Borre. Mons, Belgium.

Meganeura Brongn. Wings variable in size, long and slender, but broadest at base; scapular vein simple; all veins below this, except the simple internomedian, with very abundant, closely-set, long, and mostly simple branches. Carboniferous. Two species. Commentry, France.

Ædœophasma Scudd. Wings of large size, broad, broadest in the middle; scapular vein simple; all below this with abundant, closely-set branches, forking abundantly toward their distal ends. Carboniferous. *A. anglica* Scudd. England.

Goldenbergia Scudd. Wings of moderate size, long and slender, generally broadest near the middle, but not prominently, the tip generally rounded. Scapular vein simple; branches of other veins oblique, curving down to and striking obliquely the lower margin of the wing, those of the externomedian vein occupying at least one-third of it; anal area extending nearly to the middle of the wing; no intercalary veins. Carboniferous. Five species. Bavaria, Saarbrück basin.

Haplophlebium Scudd. Wings of moderate size, exceedingly long and slender, the veins with rare dichotomosis; with or without intercalaries. Carboniferous. Two species. Nova Scotia and Pennsylvania.

Paolia Smith. Wings of variable size, long and slender; branches of veins dichotomizing strongly and running in a longitudinal direction, so that the externomedian branches occupy only a slight portion of the lower margin; no intercalaries. Carboniferous. Four species. Illinois, Indiana, and Pennsylvania.

In this section will probably fall *Archegogryllus priscus* Scudd., founded principally upon what appears to be a saltatorial leg of an insect. Carboniferous. Ohio.

2. Section **NEUROPTEROIDEA** Scudder.

1. Family **Palephemeridæ** Scudder.

Ancient May-flies, in which the lower externomedian stem seems to be formed on the same plan as the upper stem.

Here are placed three very different insects: *Platephemera antiqua* Scudd., from the Devonian of New Brunswick; *Ephemerites Rückerti* Gein., from the Lower Dyas of Saxony; and *Palingenia Feistmantelii* Fritsch, from the Carboniferous of Bohemia.

2. Family **Homothetidæ** Scudder.

Mediastinal vein terminating on the costa; scapular vein with no inferior branches; externomedian vein, usually the most important in the wing, conspicuously branched; internomedian vein similar to the last.

Acridites Andree. Remarkable for the great length of the mediastinal vein and its uniform distance from the margin. Carboniferous. *A. priscus* Andree (probably a hind wing). Bohemia.

Eucænus Scudd. Body stout; the prothoracic segment twice as broad as long; abdomen ovate; fore wings with the mediastinal vein straight, terminating before the apical third of the wing with numerous straight branches; scapular with similar branches ending half way between the mediastinal and the tip; externomedian important, with distant branches. Carboniferous. *E. ovalis* Scudd. Mazon Creek, Ill.

Gerapompus Scudd. Body slender; the prothorax as long as broad; fore wings well rounded, the mediastinal arcuate like the costa, with infrequent simple branches; scapular ending near the tip. Carboniferous. *G. blattinoides* Scudd., *G. extensus* Scudd. Mazon Creek, Ill.

Anthracothremma Scudd. Body stout; the prothorax several times broader than long; wings subequal and elongated; the scapular vein arcuate and nearly reaching the tip; externomedian vein with numerous parallel branches, mostly simple. Carboniferous. *A. robusta* Scudd. Mazon Creek, Ill.

Genopteryx Scudd. Internomedian vein with branches very similar to those of the externomedian vein, the outermost in close proximity to the innermost branches of the latter. Carboniferous. *G. constricta* Scudd. Mazon Creek, Ill. *G. lithanthraca* Gold. sp. Saarbrück.

Cheliphlebia Scudd. Body rather slender, but wings large and coarse, without cross-veins; internomedian vein extending far toward the tip of the wing with many oblique branches. Carboniferous. *C. carbonaria* Scudd., *G. elongata* Scudd. Mazon Creek, Ill.

Genentomum Scudd. Wings large, elongated, with coarse venation and abundant cross-veins. Mediastinal vein very long, with numerous branches to the costa; other branches very distant and stout, the externomedian separated more widely than usual from the scapular, especially in the hind wing. Carboniferous. *G. validum* Scudd. Mazon Creek, Ill.

Didymophleps Scudd. All the veins and branches above the internomedian longitudinal and nearly parallel, nearly all the lower half of the wing being occupied by the oblique branches of the internomedian vein. Carboniferous. *D. contusa* Scudd. Vermilion County, Ill.

Homothetus Scudd. Mediastinal vein extremely long, scarcely surpassed by the scapular, and with scarcely any branches to the costa; externomedian vein with only a few branches in the outer fourth of the wing. Devonian. *H. fossilis* Scudd. New Brunswick.

Mixotermes Sterz. Mediastinal vein terminating at about the middle of the wing; externomedian with several distant oblique branches, the basal one thrown off far before the middle of the wing. Carboniferous. *M. lugauensis* Sterz. Lugau, Germany.

Omalia macroptera Coem.-Ben. probably belongs near here.

3. Family **Palæopterina** Scudder.

Mediastinal vein terminating on the scapular, not far from the middle of the wing; scapular vein with one inferior branch, which carries a few inferior longitudinal offshoots to the tip of the wing; externomedian vein less conspicuous than the scapular branch, often simple; internomedian conspicuously branched with oblique offshoots.

Miamia Dana. Scapular vein lying close beside the mediastinal, its course straight, its main branch arising near the middle of the wing and nowhere very distant from the main stem. Carboniferous. *M. Bronsoni* Dana. Illinois.

Propteticus Scudd. Scapular vein widely separated from the mediastinal, its course arcuate, its main branch arising near the base of the wing, parting rather widely from the main stem. Carboniferous. *P. infernus* Scudd. Illinois.

Dieconeura Scudd. Externomedian vein entirely simple; internomedian vein of unusual importance, extending far toward the extremity of the lower margin. Carboniferous. *D. arcuata* Scudd. Illinois. *D. rigida* Scudd. Pennsylvania.

Strephocladus Scudd. Externomedian vein simple, united by a prominent cross-vein with the main scapular branch near the base of the latter; internomedian vein terminating near the middle of the lower border, with numerous parallel branches arising from its superior surface and terminating on the lower border of the wing. Carboniferous. *S. subtilis* Kliv. sp. Schiffweiler, Germany.

Aethophlebia Scudd. Internomedian vein terminating before the middle of the lower border, emitting a single main branch beyond its middle, which is superior and, with the median fork of the externomedian and the larger part of the main scapular branch, forms a continuous adventitious vein crossing diagonally the course of the principal nervules of the wing; the ultimate offshoots of the externomedian vein arise indifferently from the main vein and the principal branch and are parallel and similar to the offshoots of the veins above. Carboniferous. *A. singularis* Scudd. Illinois.

4. Family **Xenoneuridæ** Scudder.

Mediastinal and scapular veins as in the Palæopterina; externomedian vein amalgamated at the base with the scapular and beyond the middle branching conspicuously; internomedian vein divided at the base into two simple branches. *Xenoneura antiquorum* Scudd. Devonian. New Brunswick.

5. Family **Hemeristina** Scudder.

Mediastinal vein terminating on the costa; scapular vein with one inferior branch arising in the basal half of the wing, running parallel to the main vein and supporting a considerable number of subequidistant oblique branches, occupying the apex or more than the apex of the wing; externomedian variable, generally branching considerably in its apical half; internomedian similar to the externomedian, but generally less important.

Lithomantis Woodw. Prothorax with large lateral lobes. Mediastinal vein farther from the margin in the middle than at base of wing; internomedian area fully as extensive as the externomedian. Carboniferous. *L. carbonaria* Woodw. Scotland.

Lithosialis Scudd. Mediastinal vein gradually approaching the margin all the way from the base. Internomedian area far less extensive than the externomedian. Carboniferous. *L. Brongniarti* Mantell sp. Coalbrookdale, England. *L. bohemica* Novák sp. Bohemia. *L. carbonaria* Germ. sp. Wettin, Germany.

Brodia Scudd. Scapular vein parallel to border; offshoots of its main branch distant, curving strongly downward, occupying a large proportion of the wing; base of the main scapular branch connected by a strong longitudinally oblique cross-vein with the externomedian. Carboniferous *B. priscotincta* Scudd. Tipton, England.

Pachytylopsis Borre. Scapular vein arcuate, approaching the border gradually almost from the base; scapular offshoots longitudinally oblique. Carboniferous. *P. Persinairei* Borre. Mons, Belgium.

Lithentomum Scudd. Main scapular branch with a single or at most two branches, which are almost wholly longitudinal. Devonian. *L. Harttii* Scudd. New Brunswick.

Chrestotes Scudd. Main scapular branch straight, close, and parallel to the main stem, with comparatively few offshoots; principal anal vein deeply impressed. Carboniferous. *C. lapidea* Scudd. Mazon Creek, Ill.

Hemeristia Dana. Scapular branch strongly arcuate, at its base distant from the main stem, and at first taking the course of its basal offshoot. Carboniferous. *H. occidentalis* Dana. Mazon Creek, Ill.

6. Family **Gerarina** Scudder.

Mediastinal terminating on the costa; scapular vein the most important in the wing, with several offshoots, all arising from the main stem; externomedian vein with offshoots closely resembling those of the scapular vein, but generally less important; internomedian still less important, sometimes simple.

Polyernus Scudd. Body moderately stout; wings rather broad; mediastinal vein extending nearly to tip of wing; branches of scapular vein inequidistant at origin, very longitudinal, closely crowded and ramose, and yet hardly more important than the externomedian vein. Carboniferous. *P. complanatus* Scudd. Mazon Creek, Ill. *P. laminarum* Scudd. Pittston, Pa.

Gerarus Scudd. Body slender, tapering greatly anteriorly; wings slender; mediastinal vein variable; branches of scapular vein numerous, more or less longitudinal, simple or forked, occupying much more space than the branches of any other vein. Carboniferous. *G. vetus* Scudd., *G. mazonus* Scudd., *G. Danæ* Scudd. Mazon Creek, Ill.

Adiphlebia Scudd. Body rather stout and equal; wings rather broad; all the nervules simple, arising from their stems near the base of the wings, subparallel and longitudinal. *A. Lacoana* Scudd. Mazon Creek, Ill.

Megathentomum Scudd. Wings of great size, remarkably broad and rounded; most of the veins dividing into principal branches near the base, the branches longitudinal and again forking only near the margin. Carboniferous. *M. pustulatum* Scudd. Mazon Creek, Ill. *M. formosum* Gold. sp. Fischbach, Germany.

3. Section **HEMIPTEROIDEA** Scudder.

Eugereon Dohrn. The thoracic joints are twice as broad as long, while the head is slender, less than a fourth their width, with lancet-shaped mouth-parts and filiform multiarticulate antennæ; front and hind wings similar in size and shape and generally in structure, being long and elongated; mediastinal vein distant from, parallel to, and connected by transverse veins with the margin; scapular with a principal branch which parts widely from it; the nervules, which strike the lower margin, curve downward rapidly as they approach it; front legs very long, the tibiæ nearly twice the length of the femora. Permian. *E. Böckingi* Dohrn. Birkenfeld, Germany. Fritsch indicates a second species from Nyřan, Bohemia.

Fulgorina Goldenb. Mediastinal and scapular veins both terminating on the costal margin in the outer half of the wing, the latter with several basal branches, from the outer of which, which runs in close proximity to the main vein, most of the forking nervules take their rise; branches of the externomedian superior and parallel to the scapular branches; internomedian forked distally, the branches of the upper fork superior, of the lower fork inferior; anal area separated by an emargination from the rest of the wing. Permian. *F. Ebersi* Dohrn (sp.). Saarbrück basin.

The other species referred to Fulgorina as well as Goldenberg's *Macrophlebium Holleberi* are probably hind wings of Palæoblattariæ.

Phthanocoris Scudd. An archaic heteropterous type, in which the front wing is already differentiated in structure from the hind wing, a large corium being present, distinct from the membrane, as well as a very narrow, unimportant clavus, the sutura clavi arising below the middle of the wing and reaching to the extremity of the corium; no embolium or cuneus exists and the mediastinal and scapular veins are widely separate at base. Carboniferous. *P. occidentalis* Scudd. Missouri.

4. Section **COLEOPTEROIDEA** Scudder.

These are perhaps indicated by the different borings brought to notice by Geinitz in the Coal Measures of Saxony and by Brongniart in the Carboniferous limestone of Autun. *Troxites Germari* Goldenb., from Saarbrück, is probably no insect at all—perhaps a fossil fruit.[1]

Brongniart has recently figured and briefly described an exceedingly interesting wing from the middle Silurian sandstone of Calvados, France, which he considers one of the Palæoblattariæ and has named *Palæoblattina Douvillei.* As a sketch kindly furnished me by Mr. Brongniart does not appear to support this reference, it is here placed at the end of the Palæodictyoptera, awaiting the fuller details concerning it promised by Mr. Brongniart.

B.—HETEROMETABOLA Packard.

Body generally bulky, flattened, and ill-constructed for varied flight. Prothorax large; the thoracic joints loosely compacted; abdomen generally sessile; mouth-parts generally mandibulate; front wings more or less coriaceous or with numerous and thickened veins, generally smaller than the hind wings, often reticulate. Metamorphosis generally incomplete, the pupa then active.

1. Order ORTHOPTERA Olivier.

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(See, also, pp. 32 and 36.)

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Body usually robust, often depressed or compressed; the integument coriaceous; ocelli generally present. Antennæ generally long, with rare exceptions simple and filiform. Mouth-parts adapted for biting; mandible stout, labium bifid. Pronotum large and distinct. Front wings coriaceous, in the flying species much smaller and especially narrower than the hind wings, which are plaited and sometimes transversely folded in repose, the anal area being very largely developed; membrane of both pair reticulate, with quadrangular cells. Female usually provided with an ovipositor. Metamorphosis incomplete; terrestrial throughout life.

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[1] See foot-note, p. 106.

1. Family **Forficulariæ.**

The earliest record we have of earwigs is in the Lias of Schambelen, where an extinct genus, Baseopsis Heer, is found, which Heer looks upon as "a remarkable connecting link between the Orthoptera and the Coleoptera." Unfortunately the forceps are not preserved. The only other Mesozoic species is an obscure form from Solenhofen, called Forficularia by Weyenbergh.

In the Tertiaries they are more abundant, though rare. Menge and Gravenhorst speak of their occurrence in amber, Serres catalogues them as found at Aix, and four species are figured by Heer and Massalongo as occurring in the beds of Oeningen and Monte Bolca. But they are more abundant in American rocks, eleven species being found at Florissant, Colo.; all are referred to a single genus, Labiduromma Scudd., with unusually large eyes; some of them are of very large size, and some are preserved with the hind wings fully expanded, showing that as early as the Oligocene the peculiar structure of these organs was already fully developed.

2. Family **Blattariæ.**

This family is one of the most interesting of all that occur in Mesozoic rocks, as it is the only one at all well represented in the Trias. Reference has already been made to the genera of Palæoblattariæ (Etoblattina, Spiloblattina, Petrablattina, and Poroblattina) which are found either in part or exclusively in these oldest Mesozoic rocks. In addition to them we have the three following genera of Blattinariæ in the same deposits:

Neorthroblattina Scudd. Fore-wings ovate, diaphanous; tip rounded, but a little produced; mediastinal and scapular veins blended into one, occupying nearly half the wing, the main vein gently sinuous, but not reaching the apex, the veins terminating on the margin. Trias. Four species. Colorado.

Scutinoblattina Scudd. Fore-wings subtriangular, tapering, strongly convex at base, coriaceous, obscuring the venation; combined mediastinal and scapular vein straight and terminating below the apex. Trias. Three species. Colorado.

Legnophora Heer. Fore-wings ovate, coriaceous, obscuring the relations of the thickened veins and branches; mediastinal and scapular veins apparently blended and occupying nearly half the wing. Trias. *L. Girardi* Heer. Trebitz, Germany.

Cockroaches are also pretty abundant in the Jurassic rocks, over forty species having already been figured, principally from the Upper Oölite of England. Among the more interesting of the Jurassic genera, very few of which have been properly studied, are the following:

Blattidium Westw. Remarkable for the extreme length, slenderness, and equal breadth of the wings. The scapular and externomedian veins are blended and, with the internomedian vein, send long, parallel, seldom forked branches to the outer margin of the wing. Lower Purbecks. Two or three species. England.

Rithma Gieb. Wings tapering from the base, the blended mediastinal and scapular area occupying half the wing and terminating at or below the tip. In other respects closely resembling the Triassic Neorthroblattina. Lias and Oölite. Four species. England and Switzerland.

Elisama Gieb. Wings rather stout; mediastinal and scapular veins blended and occupying the upper half of the wing; externomedian and internomedian veins curving very strongly downward at base and then running longitudinally; anal area reduced to a minimum. Upper Oölite. Two species. England.

Mesoblattina E. Gein. Wings slender, resembling the preceding, but the anal area of normal or even large size, and the externomedian and internomedian veins less abruptly curved at the base. Lias and Oölite. A dozen or more species. England, Germany, and Switzerland.

Pterinoblattina Scudd. Front wings resembling a feather with its shaft and barbs, the shaft, always straight and lateral, being formed of the parallel and approximate mediastinal, scapular, and externomedian veins; the barbs, of the long, straight, and mostly simple mediastinal and externomedian veins. Lias and Oölite. Six species. England and Germany.

Mesoblattina is by far the most abundant in species, many undescribed and unfigured forms existing in British collections, and especially in that of Rev. P. B. Brodie. A species of Blabera is described by Heyden from Solenhofen. There are also a considerable number of other generic types known in Mesozoic rocks, the whole number of species, both of Palæoblattariæ and of Blattariæ, amounting to between sixty and seventy.

Of Tertiary cockroaches, the remains are in general less perfectly preserved, excepting where they occur in amber. Something like a dozen species are known, and they have mostly been described or merely mentioned under the generic names of Blatta, Blattina, or Blattidium, by Germar, Heer, Menge, Berendt, Giebel, Heyden, and others, and have been recorded from Prussian and Sicilian amber, from Oeningen, Eisleben, Rott, Spitzbergen, and Greenland. Menge and Germar refer two amber species to Polyzosteria, Heer records as many species of Heterogamia from Parschlug, while the American species from Florissant and Green River belong to Paralatindia, Zetobora, and Homœogamia.

3. Family **Mantides.**

A single very obscure wingless specimen from Oeningen, *Mantis protogæa*, has been figured by Heer, and Guérin mentions the genus as occurring in amber.

4. Family **Phasmida.**

The only Postpaleozoic fossil of this family occurring in the rocks is a single specimen from the Oligocene of Florissant, in Colorado, belonging to the genus Agathemera and not very far removed from the genus Pseudoperla, peculiar to amber, of which two species are described by Pictet. Pseudoperla is remarkable for the shortness of the mesothorax and abdomen and the straightness of the fore-femora. Besides these, according to Menge, the amber has furnished specimens of Phasma and Bacteria. Considering the abundance of walking sticks in Paleozoic rocks, the absence of their remains from Mesozoic strata is rather remarkable.

5. Family **Acridii.**

A few obscure fragments, mostly saltatorial legs, have been found in the Lias of Switzerland and Upper Oölite of England, indicating the probable presence of the group of *Truxalidæ*, to which also and to *Œdipodidæ* a few wings from the Lias of Schambelen and of Dobbertin must be referred. These have been described by Heer and Geinitz under the names of Gomphocerites and Acridiites.

The group of *Acridiidæ* proper seems never to have occurred in a fossil state, since it is not only absent from the Mesozoic rocks but from the Tertiary deposits as well, the species of which, with the exception of a single one of the *Tettigidæ*, belong, like the Mesozoic forms, to the *Truxalidæ* and *Œdipodidæ*. To the former *(Truxalidæ)* belong *Œdipoda nigrofasciolata* Heer, from Radoboj; *Gomphocerus femoralis* Heer, from Oeningen; and *Acridium Barthelemyi* Hope, from Aix, together with a species of Gomphocerus and two species of Tyrbula Scudd., from Florissant, Colo. The last named is an interesting extinct genus allied to Syrbula Stål., with clubbed antennæ, hind tibiæ abundantly spined, and comparatively small eyes. To the *Œdipodidæ* probably belong five of the species of Œdipoda described by Heer from Oeningen and Radoboj, a species mentioned by Serres as occurring at Aix, and three American species from Florissant, belonging to as many genera, two of which, falling at opposite extremities of the Œdipodan series, are extinct. The only other fossil acridian published is a species of Tettigidea, described by Heer from Oeningen under the name of *Tetrix gracilis;* but an insect from Aix allied to Chimarocephala is in the Paris museum and Woodward mentions a species of this family from the Isle of Wight. Not a single specimen of this family has been reported from amber.

6. Family **Locustariæ.**

A few representatives only of this family have been found in Mesozoic rocks. Three or four species are known from Solenhofen and figured by Germar, Weyenbergh, and Hagen; one of them, *Locusta speciosa* Münst., is gigantic and all are obscure. Another species looked upon by E. Geinitz as a Gryllacris is described from Dobbertin; and when the Mesozoic species from England, figured by Brodie and Westwood, are more carefully studied, some will probably be found to fall here.

The Tertiary forms are not numerous: two species each of Decticus, Gryllacris, and Locusta have been described by Heer, Germar, and Fritsch from Oeningen, Radoboj, the Rhenish coal, Greenland, and Freudenhain in Bohemia, while single species of Locustites and Phaneroptera are figured by Heer from Parschlug and Oeningen. Serres also reports a species from Aix, and Capellini one from Gabbro. No specimen of this family seems to have been found in amber excepting a few larval forms figured by Germar.

It is a little difficult to place the fossil forms so far recorded from Europe, but the species of Decticus described by Heer and Fritsch, from Oeningen and Freudenhain, as well as Germar's *Locusta extincta*, appear to be *Decticidæ*. *Phaneroptera vetusta* Heer, from Oeningen, seems to fall in the *Phyllophoridæ*; *Locusta grœnlandica* Heer and perhaps Serres's species, in the *Pseudophyllidæ*; the two species of Gryllacris from Radoboj and the species indicated by Capellini, in the *Gryllacrididæ*. In America a single species of each of these groups, excepting the *Decticidæ*, belonging respectively to the genera Lithymnetes, Cymatomera, and Gryllacris, has been found at Florissant, together with one species each of Orchelimum and Locusta, representing the *Conocephalidæ*, a group which does not appear to occur fossil in Europe. Thus, although the total representation of the family in the Tertiary rocks is very feeble, all its principal subdivisions are present.

7. Family **Gryllides.**

The Lias of England and Germany presents a peculiar type of cricket, that from Dobbertin having been described by E. Geinitz under the name of *Gryllus dobbertinensis*; it is the only described Mesozoic species and its exact position is not clear.

The Tertiary deposits show a considerable variety of forms, though the species are not numerous. Only a single one has been fully described from amber and a second figured from Oeningen. Serres, however, mentions seven species as occurring at Aix, of which two are said to belong to Gryllotalpa (Heer also mentions a Gryllotalpa from Oeningen) and one to Xya, while he compares the four others to species of Œcanthus, Gryllus, and Nemobius. Heer's *Gryllus troglodytes*, from Oeningen, is probably a Nemobius, and the amber species, *Gryllus macrocerus*, one of the *Trigonidæ*. Three species occur in the Green River beds of Wyoming, all belonging to a single genus closely allied to Nemobius.

2. Order **NEUROPTERA** Linné.

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Body elongated, generally cylindrical, the integument coriaceous. Antennæ of variable length, but with rare exceptions simple and filiform. Mouth-parts adapted for biting; mandibles slender. Pronotum very variable. Both pairs of wings large, membranous, subequal; the membrane reticulate, with usually polygonal cells. Female rarely provided with an ovipositor. Metamorphosis complete (Neuroptera vera) or incomplete (Pseudoneuroptera); usually aquatic in early life.

The Pseudoneuroptera have been separated from the Neuroptera proper by most recent writers, either as an independent order or, following Erichson, as a part of the Orthoptera. There does not seem to be sufficient reason for considering them a distinct order and the nature of their metamorphosis offers the most valid ground for uniting them with the Orthoptera. Their retention, as here, with the Neuroptera is, however, defensible on paleontological grounds.

1. Suborder PSEUDONEUROPTERA Erichson.

1. Family **Thysanura**.

Notwithstanding the simple structure of this apterous group, it is not known earlier than Tertiary times[1] and would scarcely be known then but for the amber inclusions. The *Collembola* have not received a careful study since they were first described thirty years ago by Koch, who was content to employ for the most part the old and comprehensive genera, Podura and Smynthurus, into which he threw seven of the ten species described. The others were referred to Paidium and a new genus, Acreagris, which Menge looks upon as only the female form of the coccid genus Monophlebus. The *Cinura* received closer attention from Menge, and they are more numerous in species, about fifteen having been described by Koch and Berendt and by Menge, and they include some remarkable forms. One of them, described under the generic name Glessaria by Koch and Berendt, is with reason looked upon by Zaddach and Menge as a larva of some other neuropterous group. Menge briefly describes three extinct genera, Lampropholis, Lepidion, and Lepidothrix, to which five species are referred. Most of the species belong to Petrobius, but there is a single species each of Forbicina and Lepisma. A single specimen of one of the Cinura has been found in the American Tertiary deposits of Florissant and is remarkable for its broad and flat femora. Florissant has also furnished in considerable abundance specimens of a very anomalous creature believed to belong here, but to form a special group of Thysanura called *Ballostoma*, coming between the Cinura and Symphyla. Its head is reduced to nothing but mouth-parts and gullet, which formed an extensible soft proboscis, which when at rest was withdrawn beneath the hood-like prothoracic joint; the legs were strongly developed, with expanded and flattened femora and tibiæ and two-jointed tarsi terminating in a single claw; the abdomen was furnished with apical hooks apparently used for retrogressive motion. On account of the headless character of the creature it has been called Planocephalus.

2. Family **Termitina**.

It has generally been supposed that the white ants were present and tolerably well represented in Paleozoic rocks, but most of the species which have been referred to this family have been shown by recent researches to belong to the Protophasmida, and the others to various neuropteroid Palæodictyoptera. At least half a dozen species are known from the Mesozoic rocks, however, most of them from the Lias of England, Germany, and Switzerland, the most common type being the extinct genus Clathrotermes Heer, peculiar for its numerous, transverse, gently oblique cross-veins in the costal field and for the dark quadrate spots which usually accompany these and other cross-veins. If we are to follow E. Geinitz, the species must have been exceedingly variable. Two white ants also occur in the Oölite of Bavaria, which Hagen refers to Termes proper.

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[1] Since this was written, Charles Brongniart informs me that he has found a species of this group in the Carboniferous deposits of Commentry, France.

In Tertiary times they were more abundant, numbering already about one-fourth as many as the known living species; nearly every existing genus occurs, and, in addition, in American rocks an extinct genus, Parotermes, characterized by the presence of distinct inferior branches to the scapular vein, the slight development of the internomedian vein, with the large development of the externomedian, which runs more closely than usual to the scapular vein and has unusually longitudinal branches. The genera of Termitina are divided by Hagen into two sections, according to whether the scapular vein is branched or not; about two-thirds of the recent species belong to the section with simple scapular and one-third to the other section, while the proportion is exactly reversed in Tertiary types. Of the several genera, Parotermes is represented by three species at Florissant; Calotermes, by three species in amber and at Rott; Termopsis, by three in amber; Hodotermes, by six species at Oeningen, Radoboj, Schossnitz, and Florissant, but curiously none in amber; Termes, by three species in amber, at Oeningen, and at Radoboj; and Eutermes, by four species, equally divided between Radoboj and Florissant. Besides these, species have been indicated from Sieblos, Monte Bolca, and the Isle of Wight. All the specimens so far found, with two exceptions, have been winged; a single larva has been found in amber and one at Florissant. There is probably no group of Tertiary insects concerning which our knowledge is more exact than is the case with the white ants. Hagen has examined over one hundred and fifty specimens from amber and twenty-five specimens have been obtained from Florissant.

3. Family **Embidina.**

Of this anomalous and limited group, which Wood-Mason has recently attempted to show should be removed to the Orthoptera, a single species, *Oligotoma antiqua* Pict. sp., from amber, has been found fossil, represented, however, only by larval forms.

4. Family **Psocina.**

This group has been found fossil only in amber, but here in considerable abundance, since several of the species are represented by twenty, thirty, or even sixty individuals, and fifteen species are recognized, about one-ninth the number of living species known, but nearly one-half as many as the species now living in Germany according to the latest monograph by Kolbe. These fossil species are divided among ten genera as follows: Troctes, 1; Sphæropsocus, 1; Empheria, 2; Archipsocus, 2; Amphientomum, 1; Epipsocus, 1; Cæcilius, 3; Philotarsus, 2; Psocus, 1; Elipsocus, 1. The genera Sphæropsocus, Empheria, and Archipsocus are peculiar to amber; the first mentioned, a most remarkable form, has the front wings developed into the semblance of elytra. It is worthy of note that, while in the existing fauna of Europe the groups to which Psocus and Elipsocus belong embrace about half the species, they include only one-seventh the amber fauna. Hagen and Kolbe are at variance on the interpretation of these facts.

5. Family Perlina.

With the exception of a fossil from the Eocene of the Isle of Wight, referred to this family, and of a species of Leuctra described by Hagen from the Miocene of Rott, all our knowledge of the Perlina in ancient times is through the amber deposits. Thirteen species are known, belonging to the genera Perla, Tæniopteryx, Leuctra, and Nemura, all existing genera, and the species present no peculiarities worth special mention, being similar to existing types in north temperate regions, though in no case identical with them. It is worth remarking, however, that the number of species known from Prussian amber is nearly half that of those now living in Austria.

6. Family Ephemerides.

Undoubted remains of four or five species of this family occur in the Oölite of Solenhofen, some of very large size, most of which have been described under the generic name Ephemera, but one, in which the neuration, so far as it goes, is perfectly preserved, has been referred to a new genus, Hexagenites. Eichwald also describes and figures under the name of Ephemeropsis a larva found in the Siberian Jurassic rocks.

Our knowledge of Tertiary species comes largely from amber inclusions, but Heer and Scudder each describe a species of Ephemera from Oeningen and Florissant, and the latter distinguishes in addition five species from Florissant in an immature state. Wilkinson has also found a species in Australia. The amber species are eight in number, three of which are species of Baetis and the others are distributed among the genera Leptophlebia, Palingenia, Potamanthus, and Cronicus, the last an extinct genus allied to Heptagenia, distinguished from it by the four-jointed forceps of the male and the shortness of the middle anal bristle.

7. Family **Odonata.**

The strongly limited group of dragon flies makes its appearance in the Lias in considerable variety and apparently as highly specialized as to-day, for no less than four tribes are present, the true Agrionina and the Cordulina alone being absent. *Æschnidæ* are the most abundant, the *Æschnina* being represented by a species of Æschna at Schambelen and the *Gomphina* by one species each of Petalura and Gomphoides from England. *Calopterygina* come next, with one species each of Tarsophlebia and Heterophlebia, both extinct genera, also from England, and finally a species of Libellula from England. The same relation holds in passing upward into the Oölite, where the Agrionidæ are added. Here we have thirty-two species, of which half are *Agrionidæ:* four *Agrionina*, and twelve *Calopterygina*, of five genera, mostly extinct, namely, Isophlebia, 2; Heterophlebia, 2; Stenophlebia, 3; Tarsophlebia, 1; and Euphæa, 4; three are *Æschnina*, of the genera Anax and Æschna; eight *Gomphina*, of some undetermined genera, besides Petalura and Petalia; and finally five *Libellulina*, of about as many genera, yet undescribed. A species of Gomphina has also been found in the Wealden of England. The lithographic slates of Bavaria afford numerous, sometimes wonderfully preserved, dragon flies, called by the workmen Stangenreiter or Schladen-Vögel, which have been carefully studied by Hagen. They lie on the stone with expanded wings and are generally larger than modern types; sometimes the most delicate veins are perfectly preserved. Most of them are referred to extinct genera.

Considering the comparative abundance of this group in the secondary rocks, one would expect to find a better representation in the Tertiaries than is the case, for, even counting all the species founded upon the immature stages as distinct from any of those established upon wings, the Tertiary species are less than twice as numerous as those from the secondary rocks. The subfamilies are about equally represented, though the *Agrionidæ* are a little in excess, and the species are very unequally distributed among the tribes. Thus there are twenty-two species of *Agrionina:* of the genera Agrion, 7; Lestes, 5; Argya, 1; Platycnemis, 2; Sterope, 1; Dysagrion, 3; Podagrion, 1; and Lithagrion, 2, the last four genera being extinct; while there is but a single species of *Calopterygina* known by a pupal form, from amber, a curious reversal of the proportion in Mesozoic rocks. The *Æschnidæ* are more equally balanced between the tribes, the *Gomphina* being represented by six species, of the genera Gomphus, Gomphoides, Ictinus, and Petalura, and the *Æschina* by nine, of the genera Æschna, 8, and Anax, 1. The *Libellulidæ*, however, have again only a single species of *Cordulina*, but sixteen species of *Libellulina*, all except one, a Celithemis, referred to Libellula in a broad sense. Nearly every locality where Tertiary insects are found, even including amber, has supplied its quota of this family, and some localities, such as Oeningen, have furnished the larvæ and pupæ in great numbers.

2. Suborder NEUROPTERA VERA Erichson.

1. Family **Sialina.**

This group was well represented in Mesozoic times, but the species have never been carefully studied or compared. Three species are found as far down as the Trias (of Switzerland), and referred to Chauliodites, while in Oölitic rocks are found, especially in the Lias and Purbecks of England, but also in the Dobbertin Lias, a considerable number of types, which have been referred to species of Rhaphidium, Sialium, Chauliodites, and Hagla, of which the last is the prevailing type. *Mormolucoides articulatus* Hitchc. is the larva of a species of this group found abundantly in the new red sandstone of the Connecticut River in New England, and is the oldest larval form of insect which has been detected. An interesting relic is also found in the Laramie group of Colorado in the immense oötheca of Corydalites, an insect allied to Corydalis, preserved in considerable numbers, and from which the eggs can be extracted. Marquis Saporta informs me that entirely similar remains are found in the lower Garumnian beds of Provence, France.

In Tertiary deposits this family is rare. In Europe it is known only from amber, and is there represented by one species each of Inocellia and Chauliodes; in America only the section of *Rhaphidiidæ* is found, but of this no less than four species of Inocellia and one of Rhaphidia, from the single locality Florissant; all these Tertiary genera exist at the present day.

2. Family **Hemerobina.**

The only Mesozoic forms which can certainly be referred to this family are those reported from Solenhofen. Hagen catalogues a Chrysopa, an Apochrysa, and a Nymphes. Weyenbergh figures a Chrysopa and two species of Hemerobidæ, one of which may very likely be an Apochrysa, and the actual species be thus reduced to four. All references of English secondary insects to this family appear to be erroneous.

In Tertiary times the species do not appear to have been numerous, but they represent nearly every one of the principal groups. Of the *Myrmeleonidæ*, an obscure species, from Radoboj, is referred by Charpentier to Myrmeleon, and Burmeister and Berendt mention seeing the same genus in amber, but they probably mistook something else for it. Of *Ascalaphidæ* Oustalet describes an Ascalaphus from Le Puy, and Hagen a Suphalasca from Stösschen. Neither *Nemopteridæ* nor *Mantispidæ* have been found, but *Hemerobidæ* and *Chrysopidæ* are not uncommon. Of the former, two species of Hemerobius, besides a larva, are described from amber, and another species is mentioned from the Isle of Wight; one species each of Nymphes and Osmylus is found in amber, and a second species of Osmylus from Florissant. All these are existing genera, but an extinct genus, Bothromicromus, remarkable for its numerous sectors, occurs in British Columbia. Two other extinct genera occur in Colorado in the next group, the *Chrysopidæ*, Palæochrysa with one and Tribochrysa with three species. A species doubtfully referred to the *Chrysopidæ* is figured by Andrae from Thalheim, and a Coniopteryx from amber represents the *Coniopterygidæ*.

3. Family **Panorpidæ.**

To this family have generally been referred a considerable number of small wings occurring almost exclusively in the English and German Lias, to which the generic term Orthophlebia was applied by Westwood. Apparently it covered a considerable variety of forms, a dozen or more species having been named and many more being known, embracing a considerable range of neuration. In general the wings were of small size and had only faint cross-venation, if any, and the scapular and externomedian veins (which, being much bifurcated, bear almost all the branches) are blended at the base. Giebel has referred one of them to Panorpa, but it is of the same general character as the others, which form a distinctively oölitic type of Neuroptera, ranging as high as the Purbecks.

Nothing of this type appears in the Tertiaries, where Panorpidæ are very rare. Three species of Bittacus are described from amber and Radoboj and two species of Panorpa from amber and Colorado. The amber species of the latter genus is of a uniform ash-gray, but the species from Florissant is heavily banded, more so, indeed, than in modern types. Besides this, Florissant furnishes an extinct genus Holcorpa, with one species, remarkable for the complete absence of any cross-nervules, in which it reminds us of the Mesozoic forms; but, unlike them, it is conspicuously marked with large pale spots on a dark ground.

4. Family **Phryganidæ.**

The name of Phryganidium was given to a wing from the Lower Purbecks of England by Westwood, and, following him, E. Geinitz has described a number of species from the Lias, where this type of wing seems to be abundant and rather easily confounded with the species of Orthophlebia. These seem to be the sole representatives of the Phryganidæ in the Mesozoic rocks, excepting a tube-like larval case described by Fritsch from the Cretaceous of Bohemia.

Similar larval cases, made of minute particles of stone or of shells cemented together, have been found in various Tertiary deposits, at Oeningen, at Leistadt near Dürckheim, at Lewes in England, in Wyoming, even in amber, but particularly in Auvergne, where the so-called indusial limestone, often 2 to 3 meters thick and of wide extent, is formed of their relics. These were described by Bosc eighty years ago. Excepting in America, however, remains of the imago have rarely been found in the rocks themselves, single examples being known at Aix, Parschlug, and Manebach, in the Isle of Wight, and in Greenland; and their absence is the more unaccountable since they are more numerous in amber than any other group of insects excepting Diptera and comprise more than half the specimens of Neuroptera and Pseudoneuroptera combined. Twenty-five species have been described by Hagen and Pictet, and several others mentioned, while nearly as many are known from Florissant. They belong largely in both cases to *Hydropsychidæ*, Polycentropus being the prevailing type in amber and Derobrochus in Colorado. This last is an extinct genus allied to Polycentropus, but distinguished by the length of its cells and the apparent want of any fifth apical cell. The other groups, represented both in amber and at Florissant, are the *Phryganidæ* proper, to which the remains in the rock deposits of Europe also belong; the *Limnophilidæ*, to which group most of the larval cases probably appertain; and the *Leptoceridæ;* while the *Hydroptilidæ* and *Rhyacophilidæ* are only known, and sparingly, from amber.

3. Order **HEMIPTERA** Linné.

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Body usually ovate and flattened, especially above; the integument coriaceous. Head more or less imbedded in the prothorax. Eyes small, ocelli generally present. Antennæ of variable length, filiform, most of the joints long. Mouth-parts prolonged into a beak adapted for piercing and sucking; the lancet-shaped mandibles and maxillæ, the latter without palpi, lying in a partly closed tube formed by the labium. Pronotum large and distinctly marked, though soldered broadly to the rest of the thorax. Mesothoracic scutellum large and distinctly marked. Front wings larger than the hind pair, either coriaceous at base and more or less membranous at tip or wholly membranous, but then of firmer texture and with stouter veins than the hind wings, and often coriaceous at extreme base; veins of both wings generally few and distant, excepting next the front edge; when reticulate, the cells quadrangular; wings never folded. Legs slender, occasionally expanded, with never more than three tarsal joints. Metamorphosis (excepting in the male Coccidæ) incomplete. The terrestrial or aquatic habits (as the case may be) persistent throughout life.

1. Suborder HOMOPTERA Latreille.

1. Family **Aphidæ.**

A few unquestionable remains of this family are found in the English Wealden, one species, *Aphis valdensis* Brodie, having the characteristic neuration of the wing preserved, showing that it belonged to the *Schizoneurinæ.*

In Tertiary rocks, notwithstanding their delicacy and small size, they are not infrequent. About one hundred specimens, for instance, have been found at Florissant, including about eight species, most of which are referred by Buckton to extinct genera; and Menge's collection of amber insects in 1856 included fifty-six specimens of plant-lice. Besides this they have been found at Oeningen, Radoboj, Aix, Ain, and in British Columbia. Most of the species have been referred to Aphis (12), and Lachnus (8), and so belong, like the bulk of living species, to *Aphidinæ* proper, but Heer describes from Oeningen a Pemphigus, one of the *Pemphiginæ*, Berendt mentions a Schizoneura from amber, and one of the Florissant species also belongs to the *Schizoneurinæ.*

2. Family **Coccidæ.**

The only known fossils of this group are some that occur in amber. Three species referred to Monophlebus were described and figured by Germar, and Menge has since added short descriptions of half a dozen species referred to Aleurodes, Coccus (2), Dorthesia, and the extinct genera Ochyrocoris and Polyclona. The female of one of the species of Monophlebus was taken for one of the Poduridæ by Koch and considered the type of a new genus, Acreagris.

3. Family **Fulgoridæ.**

The oldest known member of this group is a very obscure fossil from the middle Oölite of Solenhofen, which Weyenbergh considers a Lystra; but the middle Oölite of England has furnished a few species referred doubtfully by Brodie to the genera Ricania, Cixius, Asiraca, and Delphax, the true relationship of which is still obscure; other Solenhofen species have been referred to Ricania, but are found to belong to the cockroaches (Pterinoblattina).

The family is fairly well represented in Tertiary rocks, some thirty species being known, distributed among half as many genera. The amber species comprise more than half the whole number, and are mostly referred to Cixius, but also to Pœocera, Pseudophana, Flata, and Ricania. The European rocks have furnished single species of Asiraca (Aix), Pseudophana (Oeningen), and Tettigometra (Radoboj), while from America we have single species of Planophlebia (an extinct genus), from British Columbia; of Aphana and Delphax, from Utah; and of Mnemosyne, Lystra, Fulgora, Cixius, Aphana, and the extinct genus Lithopsis, from Wyoming, besides some large undescribed forms from Florissant.

4. Family **Membracides.**

A single species found in the Oölite of Belgium and mentioned by de Borre as probably belonging near Tettigonia is the only Mesozoic form referable here.

Tertiary species are tolerably abundant and have been mostly referred to existing genera: Acocephalus, 3, sp.; Jassus, 2; Tettigonia, 6; Bythoscopus, 4; Typhlocyba, 5; and Cœlidia, 1; though Heer refers one Radoboj species to an extinct genus, Dictyophorites; five species, from Oeningen, Radoboj, and Aix, to Cicadellites; and one Oeningen species each to Membracites and Ledophora. More than half the known species come from Radoboj or amber, but four species are known from Oeningen, three from Aix, two from Utah, and one each from Wyoming, British Columbia, Florissant, and Stösschen.

5. Family **Cicadellina.**

Nearly a dozen species, referred loosely to Cercopis, Cercopidium, Cicadellium, and some to "Cicada," have been described from the Lias of Dobbertin and Schambelen and the upper Oölite of England, but they have not yet been carefully studied.

In Tertiary deposits they are the most abundant of Homoptera. No less than sixteen species of Cercopis are described, more than half of them from Radoboj, the others from Oeningen, amber, and British Columbia. A genus allied to Ptyelus is represented at Florissant by a dozen or more species, very abundant in individuals, and seven species of Aphrophora are known from amber, Aix, Oeningen, Radoboj, and Greith, on the Upper Rhone. Besides these, an interesting extinct gigantic genus, Petrolystra, with two species, remarkable for the coloration of the wings, has been found at Florissant. Heer describes a Cercopidium from the Miocene of Greenland and Woodward refers a species found in the Eocene of the Isle of Wight to the existing *Triecphora sanguinolenta.*

6. Family **Stridulantia.**

The presence of this group in Mesozoic rocks, so far as published data are concerned, rests mainly on disputed or disputable data. Two species coming from Solenhofen, referred by Weyenbergh to Cicada, are very obscure objects. Several other species from England which belong to the preceding family have been referred to Cicada. But Brodie possesses what appears to be the pupa of a Cicada from the Lias of England and the Stonesfield slate has furnished a wing of large size, named *Paleontina oolitica* by Butler and by him considered a butterfly, which is looked upon by Scudder as belonging to this family of Homoptera.

In the Tertiaries three species found at Radoboj and one at Oeningen have been referred by Heer to the genus Cicada and are species of medium size; but besides these Serres refers to a species of the same genus at Aix and Berendt and Burmeister state that it occurs in amber, while Bleicher mentions a specimen of this family from the Tongrian of Rouffach in Alsace. None have been discovered in America and none in amber.

2. Suborder HETEROPTERA Latreille.

1. Family **Notonectidæ**.

This family of water bugs makes its first appearance in the Tertiaries, and then in very scanty numbers. Two species of Corixa are known, one each from Oeningen and Stösschen, and one has been mentioned from Florissant. One species of Notonecta also is known from Kutschlin, another from Rott, a third is mentioned from Aix, and a fourth occurs at Florissant.

2. Family **Nepidæ**.

Species referred to Naucoris and Nepa, occurring in the Oölite of Solenhofen, are the only known representatives of this family in Mesozoic times.

To the same genera are referred two species occurring in the Tertiary deposits of Oeningen, where, also, a species of Diplonychus is found. Berendt states that a species of Nepa occurs in amber and Serres refers to one found at Aix, where, according to Hope, a species of Ranatra also occurs.

3. Family **Belostomidæ**.

To the genus Belostomum have been referred three species from the Oölite of Solenhofen. One of these was originally described by Germar under the name of *Scarabæides deperditus*, under the supposition that it was a beetle. Dr. Zittel informs me that some specimens in the Munich museum preserve the stout legs and principal wing nervures, showing a complete general agreement with Belostomum. Another species referred here by Germar under the name of *Belostomum elongatum* is considered by Assmann to be rather a Hymenopteron, allied to Sirex. (See p. 96, note.)

In the Tertiaries, two species of Belostomum have been figured, one from Oeningen, the other from the Rhenish brown coal.

4. Family **Hydrometridæ.**

Obscure species referred to the genera Velia and Hydrometra have been found in the Oölite of Solenhofen and of England and a few genera are represented in Tertiary deposits. Species of Limnobates and Hygrotrechus have been described from Oeningen and British Columbia and of Limnacis, Halobates and Hydrometra from amber, and mention has been made of the occurrence of the latter genus and of Gerris at Aix. Halobates also occurs at Florissant.

5. Family **Saldidæ.**

Germar describes a single species of Salda from amber.

6. Family **Reduviidæ.**

Two gigantic species in the Solenhofen shales represent this family in the Mesozoic; they have been referred to the genus Pygolampis and an extinct type allied to it, called Propygolampis.

In the Tertiaries the true *Reduviina* are the most abundant, six species of Harpactor being found at Oeningen or Radoboj, with a species of Evagoras at Oeningen and one of Reduvius in Wyoming. Reduvius occurs also at Aix and in amber, according to Serres and Germar. Of the other tribes, as in the Reduviina, all the genera are of existing types; a single species of Pirates is found at Radoboj, one of Platymeris in amber, two of Stenopoda at Oeningen, and Serres reports a Ploiaria at Aix. A number of species of undetermined genera occur at Florissant.

7. Family **Nabidæ.**

Nabidæ of the modern genera Nabis and Prostemma are found at Oeningen, and several species of the former occur also at Radoboj and in amber.

8. Family **Aradidæ.**

The fossil species of this group are all from Tertiary deposits and have been referred to Aradus; three species have been described from amber and one from Radoboj, besides which Hope and Serres refer to a species at Aix and Scudder to two species at Florissant.

9. Family **Tingidæ.**

Half a dozen Tertiary localities have already furnished specimens of these delicate insects. Species of Monanthia are described from Oeningen and Krottensee and of Tingis from Radoboj and Prussian amber. Besides this, specimens of Tingis have been found at Aix and at Florissant.

10. Family **Capsidæ**.

Amber has furnished a large number of species of this family, all referred to living genera. Germar describes thirteen species of Phytocoris and Gravenhorst specifies without describing five species of Miris. Both Berendt and Gravenhorst mention also a Capsus from the same deposits and Curtis speaks of a Miris from Aix.

11. Family **Physapodes**.

One would scarcely look for remains of these minute insects in the rocks, and yet they are not extremely rare, eight species of the genus Thrips having been described, three each from Aix and from amber and two from Oeningen. Another species found at Aix is made the type of a new genus, Calothrips, and the rocks of Utah have furnished one species each of three genera, Melanothrips, Lithadothrips, and Palæothrips, the last two extinct and the last remarkably preserved, the microscopic hairs of the fringe of the wing being distinct enough to be counted.

12. Family **Lygæidæ**.

The two oldest insects which have been referred to this group are a Pachymerus from Strensham and a Pachymeridium from Dobbertin, both from Liassic deposits; they are both rather obscure, and almost more so are the three wings figured by Westwood from the English Purbecks, which Giebel refers to Lygæites.

In Tertiary deposits the family is comparatively abundant and widespread. No less than seventeen described species are referred to Pachymerus: From Aix, 6; Oeningen, 4; amber, 3; Radoboj, 2; Sieblos; and Utah; nine to Lygæus: from Radoboj, 3; Oeningen, 2; Sieblos, 2; Aix; and Krottensee; while Serres alludes to four species of the same genus at Aix and Heer describes five species of the extinct Lygæites from Oeningen and Radoboj. Besides this, Heer describes six species of Heterogaster from Radoboj, Aix, and Oeningen, and one extinct genus, Cephalocoris, from Oeningen, Heyden refers to a species of Micropus found at Stösschen, and Scudder describes a Rhyparochromus from Wyoming. The numerous species from Florissant are not yet worked up.

13. Family **Coreidæ**.

Our knowledge of this family in Mesozoic times is limited to the brief account and figures of Liassic species given by Heer in his Urwelt der Schweiz, who figures two and names one additional species referred to extinct genera, Protocoris and Cyclocoris. Eight species in all were known to Heer, and they are very perfectly preserved.

A considerable variety occurs also in the Tertiaries, including, according to Heer, three genera which are extinct, Berytopsis, Hermostites, and Palæocoris, each with a single species, the first two from Oeningen, the last from Radoboj; also, Coreites, which includes three more obscure forms from Radoboj and Oeningen, whose generic relation is uncertain. The same author also describes four species of Syromastes from Oeningen and two of Spartocerus from Radoboj. Oeningen has also furnished single species of Hypselonotus and Alydus; a species of the latter genus occurs in the Rhenish coal, of Leptoscelis, at Sieblos; Serres mentions a species of Coreus at Aix and Menge a species of Berytus in amber. The family is abundantly represented in the still unworked field of Florissant, where especially one or two species of Alydina are exceedingly abundant in individuals.

14. Family **Cimicidæ.**

A number of species from the English Purbecks, and even from the Lias, have been referred to this family, but all these remains are exceedingly obscure and have in no case been referred to special genera.

In the Tertiary deposits, however, this family is the most numerous and abundant of all Heteroptera, but no one of its members has been referred to extinct genera. Species of Cimex, using the term doubtless in a general way, have been mentioned by Eser as occurring in the Miocene of Unterkirchberg, by Serres, Berendt, and Schlotheim as found in amber, and by Stainton as occurring in the Pleistocene marls of Ulveston. Three species of Acanthosoma are described by Heer from Radoboj, as well as one of Phlœocoris from the same place; and, among the series of the Pentatomids, one species of Ælia, four of Eurytæna, two of Eusarcus, two of Halys, and eight of Pentatoma, all from Oeningen, besides two of the latter genus from Radoboj and one each from amber, Salzhausen, and Atanekerdluk in North Greenland. Serres also referred to three species as found at Aix, a species of Euschistus is described from British Columbia, and a considerable number of the Pentatomid series occur at Florissant. Finally, four species of Pachycoris and a species of Tetyra are found at Oeningen.

15. Family **Cydnida.**

This restricted group was tolerably abundant, varied, and widespread in Tertiary times. An extinct genus, Cydnopsis Heer, is represented by eleven species in Oeningen, Radoboj, and Aix, and the recent genus Cydnus, by four at Aix, Oeningen, and Wyoming, besides a species near Cydnus found in the Australian Tertiaries. Another extinct genus, Neurocoris Heer, has two species at Oeningen; Cyrtomenus and Æthus, one each in Wyoming; and Brachypeltus, one at Krottensee. Several species of Corimalæna and its allies are found at Florissant.

4. Order COLEOPTERA Linné.

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(See, also, pp. 32 and 36.)

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Body compact, generally subelliptical; the integument usually corneous. Head usually inserted more or less deeply into the prothorax. Antennæ exceedingly variable in length and in the form of the joints; ocelli generally absent. Mouth-parts adapted for biting; the mandibles stout, labium entire. Pronotum large, distinct, free. Mesothoracic scutellum small, but distinctly marked. Front wings corneous, nearly all traces of the veins lost, adapted to the shape of the body, separated from each other by a straight suture down the middle of the back, useless in flight. Hind wings membranous, folded transversely and longitudinally in repose; the veins few, distant, incomplete, a joint being formed near the extremity by their erasure; cross-veins very rare; reticulation absent. Metamorphosis complete, the appendages of the pupa free. Larva of three principal types (thysanuriform, eruciform, and vermiform or apodal), not corresponding to the divisions based on the main structural distinctions of the adult. Habits variable, but the aquatic forms aquatic throughout life.

1. Series RHYNCHOPHORA Latreille.

1. Family **Anthribidæ.**

This family made its first appearance in the Tertiaries. Oeningen, Rott, and Green River (Wyoming) have each furnished a pair of species, the species from Oeningen being referred to Anthribites, those from Rott to Choragus and Tophoderes, and those from Wyoming to Brachytarsus and Cratoparis. In addition, Berendt mentions a species of Anthribus from amber.

2. Family **Scolytidæ.**

Not altogether rare in the Tertiaries, being found in the earliest deposits that have yielded insects: amber, Aix, and the Green River shales. A species of Platypus is described from Prussian and another from Sicilian amber; one species each of Trypodendron and Dryocœtes, from Wyoming. Serres mentions species of Scolytus and Hylurgus from Aix. Heer describes a Hylesinus from the same place and Menge speaks of three species of this genus in his amber collection, besides larvæ of the same. Berendt and Serres also mention its occurrence in amber and Germar describes a species from the same deposit under the generic name Hylesinites.

3. Family **Calandridæ.**

A few species of this family have been recovered from the Tertiaries. Heer describes two species of Cossonus and one of Sphenophorus from Oeningen. Oustalet describes one of the former from Aix and Heyden one of the latter from Rott. Besides this, the only reference is to a species in amber, referred by Pictet to Calandra.

4. Family **Curculionidæ.**

In attempting to bring together the scattered references to this and allied families of Rhynchophora it has often been impossible, from the nature of the reference or the obscurity of the fossil remains, to determine to which family it belonged; so far as possible they have been separated, but where no clew could be obtained they have been brought under the head of the present family.

We have in this group some of the oldest Coleoptera known. One species (*Curculionites prodromus* Heer) comes from the Trias and bears the unmistakable stamp of this group. Two others described by Heer occur in the Rhaetic of Sweden, but are represented only by elytra. The Lias of Switzerland has furnished the same author seven species, of which he has figured a couple under the generic name of Curculionites and Sitonites. They occur also in different parts of the oölitic series, a species of Curculionidium being figured from the Stonesfield slate of England, and several species of Curculionites and one of Hypera from the Purbecks of England. Finally Heer figures two species from the Greenland Cretaceous under the genera Curculionites and Archiorhynchus.

Corresponding to this we find the family one of the very richest in species in the Tertiary rocks. About one hundred species have already been indicated, referred almost exclusively to existing genera; probably a nearly equal number have been found at Florissant alone, and of the amber species little is known. Menge mentions sixty-three specimens in his amber collection; Oustalet describes a species of Balaninus from Aix, and Deichmüller one from Kutschlin; Pictet mentions a Baris from Aix, and Scudder describes a Eurhinus from Florissant. Fliche found the recent *Mononychus punctum-album* in peat at Jarville. Oustalet describes a Cœliodes from Aix and Heyden a Ceutorhynchus from Rott. Distinct species of Cryptorhynchus have been found in Wyoming, at Aix, and at Rott. Heyden describes an Acalles from Rott, and Deichmüller a Chalcodermus from Kutschlin, while Hope and Serres indicate a Rhinobates as occurring at Aix. A single species of Nanophyes has been described from Rott, one of Gymnetron from Green River, and Serres indicates a Cionus from Aix. The *Tychiini* are represented by a Sibynes at Aix and a Tychius at Rott; the *Anthonomini* by a Rhynchænus at Aix and an Anthonomus at Florissant; two species of Magdalis are described by Heyden from Rott; Oustalet describes a Bagous from Corent, and from Aix one species each of the genera Hydronomus, Tanysphyrus, and Erirhinus. Notaris and Dorytomus have also been mentioned from Aix, and the latter as well as Erirhinoides from amber. Heer describes two species of Lixus from Oeningen, a genus also occurring at Aix. Heyden describes a Rhinocyllus from Rott. No less than thirteen species of Cleonus are described from Aix, Oeningen, and Corent. Besides an extinct genus, Cleonolithus, described by Bassi from Sinigaglia, a new genus Meristos is described by Murray from Nágpur in India. Species of Larinus are mentioned by Heer and Heyden from the Miocene deposits of Oeningen and Rott and the same genus was recognized by Burmeister among the insects of Aix. Eight species again of Hylobius have been obtained from various localities in Germany, Switzerland, France, Italy, and Wyoming, as well as indicated from amber; a species of Plinthus is found at Aix, another at Corent, and one of Pissodes at Sieblos, besides an indication of the latter in amber; two species of Phytonomus are found at Aix, another in amber, four of Hipporhinus, and one of Hypera, also from Aix. Two species of Apion have been described by Heer and by Heyden, from Oeningen and Rott, respectively, and other species are mentioned by Berendt as occurring in amber, and by Serres at Aix, Oustalet also describes a Coniatus from Aix; Heyden, a Eurychirus from Rott; and five species of Sitones are described from Oeningen, Rott, Aix, and Wyoming. Besides these we have eleven species of "Curculionites" of uncertain position, mostly described by Heer, from Oeningen, Radoboj, Schossnitz, Corent, Aix, Corfe, and Spitzbergen. References to Rhynchophora are also made from the following localities not otherwise mentioned: Antrim, Dorset, Bournemouth, Lexden, the Isle of Wight, the British Isles, and Nágpur (India), where they form the larger proportion of those found.

5. Family **Otiorhynchidæ.**

The only references to the occurrence of this family in Mesozoic deposits are an Anisorhynchus described by Weyenbergh from Solenhofen and a fragment of an elytron from the Cretaceous of Bohemia, which Fritsch figures under the name of Otiorhynchites.

In Tertiary deposits they are numerous, though not so numerous as the preceding family, bearing perhaps the same relation to them, in point of numbers, as at the present epoch. Phyllobius, Polydrosus, and Thylacites are all said by Burmeister to occur in amber, and the last genus has been found by Deichmüller at Kutschlin. Heer describes a Naupactus from Oeningen and Serres says one occurs at Aix. Heer also describes a diluvial Laparocerus from Madeira, Scudder a Eudiagogus from Wyoming and an Entimus from Utah, while Smith mentions a species referred doubtfully to Strophosomus as found at Peckham, England, in lower Eocene beds. A species of Ophryastes and two of Otiorhynchus are described from Wyoming, and Heer mentions four existing species of the latter genus as found in the glacial clays of Schwerzenbach, Switzerland. Heer also describes an extinct genus, Pristorhynchus, from Oeningen. Finally, of the *Brachydermi*, Heyden describes a Liparus from Sieblos, and Curtis mentions, while Giebel describes, one from Aix. Three species of Epicærus are recognized from Wyoming, two of Anisorhynchus from Kutschlin and Corent, and two of Brachyderes from Aix. No extinct genera of this tribe are yet recognized. Many unpublished forms of this family occur at Florissant.

6. Family **Byrsopidæ.**

Four existing genera of this group have been recognized in Tertiary rocks. Of Brachycerus four species are described, from Oeningen two, from Gergovie and Aix one each, and from Aix Serres recognized three species as of this family, one of which Oustalet suggests may be *Hipporhinus Heeri* Germ. Serres also refers to a Meleus at Aix, and a species of Brachymycterus has been described from Rott.

7. Family **Attelabidæ.**

Heer describes a species of Attelabus from Oeningen.

8. Family **Rhynchitidæ.**

Oeningen and Rott have each furnished two species of Rhynchites, and to the same genus have been referred single undescribed species from amber and Aix; in addition to these, a species of Antliarhinites has been described from Oeningen and one of Eugnamptus from Wyoming.

2. Series HETEROMERA Duméril.

1. Family **Stylopidæ.**

One of the most curious results of Menge's studies of the amber fauna was the discovery of an extinct genus of this abnormal type of beetles, which in its earliest stages lives parasitic in the abdomen of winged bees and wasps. A single male specimen was found, which, on account of the trifid antennæ, he named Triæna.

2. Family **Rhipiphoridæ.**

Heyden describes a Myodites from Rott and Stein a Rhipidius from amber. Berendt and Menge also mention the existence of Rhipiphorus in amber.

3. Family **Meloidæ.**

The occurrence of this family in Mesozoic rocks is exceedingly doubtful, the only claim to it being in a figure published by Weyenbergh, without comment, of a very obscure object from Solenhofen, which he names ***Meloe bavaricus.***

As to the Tertiaries, Heyden describes a Mylabris from Rott; Heer, a Lytta and a Zonites from Oeningen and a Meloe from Radoboj; the last genus and Cantharis are also mentioned by Goldfuss as occurring on the Rhine, and by Menge, Berendt, and Burmeister as found in amber. Hammerschmidt exhibited a species of this family from amber at Vienna, which Redtenbacher looked upon as the type of an extinct genus, and Menge states that among the *Cantharidæ* of his amber collection are found beautiful and remarkable objects. He also states that he possesses one specimen of amber "with seven reddish-yellow larvæ resembling Meloe larvæ at the stage when they live on flowers and then attach themselves to bees; but they possess only two claws at the tip of the two-jointed tarsi." A good many specimens of this family have been found at Florissant.

4. Family **Pyrochroidæ.**

Berendt includes in his list of amber insects a species of Pyrochroa.

5. Family **Anthicidæ.**

This family is not very rare in amber, Menge's collection containing twenty-seven specimens; but none have been described, Berendt only mentioning an Anthicus. A species of this genus has also been described from Aix by Oustalet.

6. Family **Mordellidæ.**

This family also is abundant in amber, but none have been described excepting *Mordellina inclusa* Germ. Berendt also mentions Mordella as occurring in amber.

7. Family **Œdemeridæ.**

Berendt mentions Œdemera in amber.

8. Family **Pythidæ.**

Berendt includes Anaspis among the amber insects of Prussia and Guérin mentions a species in Sicilian amber. Heer also describes a Pythonidium from the Miocene of Spitzbergen.

9. Family **Melandryidæ.**

Besides a species of Mycterus described by Heer from Oeningen, we have a Scraptia figured by Guérin from Sicilian amber, and a Hallomenus or Orchesia mentioned by Berendt from Prussian amber.

10. Family **Lagriidæ.**

F. Smith refers an amber insect figured by him to a genus allied to Statira.

11. Family **Cistelidæ.**

This family occurs in the Mesozoic rocks, Heer describing a species from the Lias of Schambelen under the name of *Cistelites insignis*.

In the Tertiaries little is known of them. Berendt mentions Cistela as found in amber and Heer describes a species of this genus from Oeningen, as well as four species, which he refers to Cistelites, from Greenland, the island of Sachelin, and Oeningen.

12. Family **Tenebrionidæ.**

An elytron found in the Lower Lias or Rhaetic of Hildesheim is figured by Roemer under the name Helopides. A species of Tenebrio is described by Weyenbergh from the middle Oölite of Solenhofen, but the upper Oölite of England has furnished a considerable number of species, nine of which have been referred by Giebel or by Westwood to Tentyrium, Pimelia, Blaps and Blapsium, Tenebrio, Crypticus, Helopium, Helopidium, and Diaperidium. They are mostly composed of fragments of elytra. (See, also, page 106, note.)

Considering its extent at the present day and the tolerable variety in Mesozoic times, the representation of this family in the Tertiaries was not very large. The Rhenish brown coal has furnished species of Boletophagus, Tenebrio, Uloma, Gonocephalum, and Platydoma; Tenebrio is also recorded from British Columbia, and Boletophagus, as well as Hopatrum, from amber. A recent species of the last-named genus, *H. sabulosum*, is stated by Meyer to be found in the marls of Hochheim. Aix has also been credited with a species of Hopatrum, as well as with Asida and Sepidium. Species of Helops have been found at Eisleben, Lausanne, and Oeningen, and one, *Helops wetteravicus*, first described by Heyden, from Salzhausen, is said by Heer to occur also in Greenland. An extinct genus, Tagenopsis, is described by Heer, from Oeningen, and *Helopini* are said by Westwood and Brodie to occur in the English Tertiaries. About twenty species of Tenebrionidæ have been found at Florissant, but they are not at all abundant in individuals.

3. Series PHYTOPHAGA Duméril.

1. Family **Bruchidæ.**

All the fossil (Tertiary) species of this family have been referred to existing genera. The brown coal of the Rhine has furnished the greatest number, viz, two species of Bruchus and one each of Caryoborus and Urodon. Oeningen has also its species of Bruchus and Caryoborus, and a species of Bruchus has been described from Utah and another indicated from Aix. A dozen or more species of this family have been found at Florissant, only one of which, a Spermophagus, has been described.

2. Family **Chrysomelidæ.**

Fairly represented in Mesozoic rocks, beginning with the Trias, a species of Chrysomelites having been described by Heer from the Lettenkohle of Rütihard, in Basel. The Lias of England has furnished several figured but unnamed species, besides two referred to Chrysomela, and Heer figures from Schambelen a couple of forms under the name of Eumolpites and Chrysomelites, of which he says it is "difficult to say what kind of leaves they might have fed upon." The Oölite of Bavaria and of England has furnished also some six species referred to Chrysomela, besides species of Cryptocephalus and Cassida in the former.

In the Tertiaries species of this family are very abundant and are almost exclusively referred to existing genera. Of the *Cassidini* we have four species of Cassida figured from Oeningen, Aix, and Rott, besides many references to the genus at Aix, in amber, and in the Lexden peat. Of the *Hispini*, Menge says that Odontota occurs in amber and Heer describes an Anoplitis from Oeningen. Of the *Galerucini* we have an extinct genus, Oryctoscirtetes, in the Florissant beds, besides three species of Galeruca described from Radoboj and Oeningen, and numerous references are at hand to the occurrence of the latter genus and of Haltica in amber. Adimonia was also found by Fliche in peat at Jarville and a Galerucella by Scudder in British Columbia. The *Chrysomelini* proper were even more numerous: eight species of Chrysomela have been described from Oeningen, Aix, and amber, besides four species of Chrysomelites from Alaska, Greenland, and Spitzbergen. Numerous references to the occurrence of Chrysomela in amber occur—a genus which, according to Menge, is the richest in numbers of all Chrysomelidæ; he even records three larvæ of this genus similarly entombed, and its occurrence at Aix and in Lexden peat is also on record; Wollaston also found in the Lexden peat a species of Oreina and three species of the same genus are described by Heer from Oeningen; three species of Lina are figured from Oeningen, Rott, and Salzhausen, a species of Plagiodera from Rott, and four species of Gonioctena from Oeningen, Aix, and Schossnitz. Colasposoma, one of the *Eumolpini*, is credited to amber by F. Smith. Cryptocephalus is described from Wyoming and is said by Menge to occur in amber. Of the *Clythrini*, Heyden describes a Labiostomis from Rott and a Clythra from Salzhausen, while Heer describes a second Clythra from Oeningen. Of the *Criocerini*, two species of Lema are figured from Salzhausen and Oeningen and two of Crioceris from Aix and amber. Of the *Donaciini*, Berendt says that Hæmonia occurs in amber and six extinct species of Donacia are described from the Quaternary at Sonnaz and Leffe, and from the older formation of Schossnitz, Oeningen, and Spitzbergen. As many existing species are recorded from the Quaternary deposits or interglacial clays of Leffe in the Val Gandino; at Chambéry, La Boise, and Ardres, in France; at Lausanne, Utznach, Dürnten, and Schwerzenbach, in Switzerland; at Hösbach, in Franconia; and at Durchheim, in Pfalz; besides which, undetermined species are mentioned from similar deposits in Flanders; at Villechétif and Vannes, in France; and at Mundesley, in England. Chrysomelidæ of undetermined genera are recorded from Creech, Schossnitz, Hérault, and Florissant, the last place furnishing over twenty species.

3. Family Cerambycidæ.

The lower, middle, and upper Oölites are all credited with some species of this family. Two species of Prionus are found in the lower members in England, and one of these also in the Dobbertin Lias; Leptura, Mesosa, and Saperdites all occur at Solenhofen, and Prionus and Lamia, in the English Purbecks. These are nearly all recognized by the elytra alone. Besides these Geinitz has described and figured in the Quadersandstein of various localities in Saxony borings of beetles in fossil wood, which are credited to insects of this family under the name of Cerambycites.

A considerable variety, though no great number of species, has been found in the Tertiary deposits; with few exceptions they have been referred to existing genera, and these exceptions all occur in the *Lamiinæ*. Thus Deichmüller refers a species from Kutschlin to Mesosites, Scudder one from Florissant to Parolamia, and Motschulsky indicates an amber species under the name of Dorcadionoides. Allied to these Heer describes a Mesosa and a Lamia from Oeningen, Heyden a Lamia and Dorcadion from Rott, and Berendt states that Lamia occurs in amber. Heer describes also two species of Acanthoderes from Oeningen and Heyden an Oberea from Rott, while four species of Saperda are described from the Miocene deposits of Oeningen and the Rhine and the same genus is recorded from amber. Casts of large insect larvæ are also sometimes found in amber, one of which is referable to Saperda. Such casts are generally very rare and have indeed not been known a great while. They all belong to larvæ of this family and the next. Of the *Cerambycinæ* proper, Leptura is recorded as found in amber, both as larva and imago. Necydalis also occurs in amber, three species of Clytus are described from Oeningen and Aix and a Trachyderes from Sieblos. Obrium and Molorchus are recorded from amber and two species are described from the Rhenish brown coal under the name of Hesthesis. Cerambyx has been found in amber, both as imago and larva, and is recorded also from Oeningen, Aix, and the Rhine. Heyden describes a Hylotrupes from Rott and Heer two species of Callidium from Oeningen. Species of this last genus have also been referred to as found in amber, at Aix, and in the Quaternary deposits of Utznach. Fifteen or twenty undescribed species of this family occur at Florissant.

4. Family **Spondylidæ**.

Two species of Spondylis are described by Giebel and Germar from amber and the Rhenish coal, and Goldfuss states that a Parandra is found in the latter. The larva also of Spondylis occurs in casts in amber.

4. Series LAMELLICORNIA Latreille.

1. Family **Scarabæidæ**.

A few representatives of this family have been found in Mesozoic deposits, and even as far back as the Lias, which has furnished in England a fragment referred to Melolontha and in Switzerland a smaller form called Aphodiites. Besides these we have in the Oölite of Solenhofen species which have been referred to Oryctes and Cetonia, and possibly some of the other larger beetles from those deposits will prove to belong here. *Scarabæides deperditus* Germ. belongs to the hemipterous family Belostomidæ. The Carboniferous fossil from Altenwald, described under the name of Troxites, is probably a fruit.

Species of this family are abundant in the Tertiaries and are almost without exception referred to existing genera. Among the *Cetonini* we have five species of Trichius and one of Valgus, described by Heer, from Oeningen. Serres speaks of members of this group as occurring at Hérault and Curtis catalogues a Cetonia from Aix. Of the *Dynastini*, two species of Pentodon are described from Rott and Oeningen, and the last has furnished a Scarabæus, a genus also recognized by Bertrand at Glarus. Among the *Rutelini*, Heyden describes an Anoplognathus from Rott, and four species of Anomala are figured from Oeningen and Rott, while a new genus, Anomalites, is established by Frič for a fossil found lying in a very natural position in a cavity of the Süsswasserquarz of Nogent-le-Rotrou. Among the *Melolonthini* Fliche recognizes the recent *Rhizotrogus solstitialis* in the peat of the Flemish coast and Heer describes an extinct species from Oeningen. Heer recognizes the the modern *Melolontha hippocastani* in the glacial clays of Schwerzenbach and describes a fossil form from Greith, and Novák another from Krottensee; while, for six other forms from Oeningen and Parschlug, Heer establishes the new genus Melolonthites. Serres also recognizes Pachypus among the Aix relics. Of the *Sericini* we have only a Lepitrix and a Serica described by Heer from Oeningen, besides a species of the latter genus mentioned by Giebel as found in amber. A species of Glaphyrus from Oeningen is the only representative of the *Hoplini* and one of Trox from British Columbia of the *Trogini*. The *Geotrupini* are more abundant, and include an extinct genus, Coprologus, described by Heer from Oeningen, a Bolbocerus from Kutschlin, with four extinct species of Geotrupes from Aix, Oeningen, and the Rhine, besides three existing species of the same genus in the Pleistocene of Vannes and in the peat below the till in Edinburgh. A species of Hybosorus from Oeningen represents the *Hybosorini*, and six species of Aphodius described from Oeningen, amber, Rott, and the bone caves of Pennsylvania, besides the mention of one from the Polirschiefer of Habichtswald, represent the *Aphodiini*. The *Coprini*, again, are both abundant and varied. Oeningen has furnished five species of Onthophagus, three of Gymnopleurus, two of Copris, and one each of Glaphyrus and Oniticellus. Curtis also recognizes *Copris lunaris* L. in the Pleistocene of Mundesley and Oustalet describes an Onthophagus from Aix; besides these, Horn recognizes in the relics from the bone caves of Pennsylvania species of Phanæus and of Chœridium. Heyden describes an Onitis from Rott and Serres recognizes Sisyphus at Aix. Some thirty species of undetermined genera of this family have been found at Florissant.

2. Family **Lucanidæ.**

Germar describes a Platycerus from the Rhine, Deichmüller a Dorcus from Kutschlin, and Motschulsky figures a Dorcasoides from amber. Platycerus is also recognized in amber by Berendt, Dorcus in the Eocene of the Isle of Wight by Woodward, and Lucanus in the Rhenish coal by Goldfuss and by Giebel. Menge also mentions the occurrence of a single Lucanid in his amber collection.

5. Series SERRICORNIA Latreille.

1. Family **Cioidæ.**

This little family is represented by a Cis and by a Microzoum described from Rott by Heyden. Berendt also recognizes Cis in amber.

2. Family **Lymexylidæ.**

Heer names, but neither describes nor figures, *Hylecœtus cylindricus*, from Oeningen; besides this, Atractocerus and Lymexylon have been recognized in amber, the latter in both the imago and the larval state.

3. Family **Cupesinæ.**

Motschulsky notes in amber a species which he calls a Cupoides, from its resemblance to Cupes, and the latter is mentioned in his list of amber insects by Berendt.

4. Family **Ptinidæ.**

Brongniart describes from the Cretaceous of Lottinghem a fragment of wood with perforations of a beetle, which he ascribes to a Bostrychus. The same genus is recorded as occurring in amber by Burmeister, Hope, and Menge, the last recognizing the larva as well as the imago. Lyctus and Apate are also both said to occur in amber, and the latter at Aix as well. Of the *Anobiinæ*, Dorcatoma, Anobium, and Ptilinus are recorded from amber, the first also in a larval condition. Anobium is stated to occur also in the Isle of Wight, and three species, as well as one of Sitodrepa, are described from Wyoming. Ptilinus is also mentioned by Heyden as found at Salzhausen, and the same author describes an extinct genus, Xyletinites, from Rott. Among the *Ptininæ*, two species of Ptinus are described by Heyden from Rott and Stösschen and the genus is also recognized in amber and at Aix. Eight or nine species of the family occur at Florissant.

5. Family **Cleridæ.**

Heer describes a Clerus from Oeningen and Giebel one from amber. Menge's amber collection contained fourteen specimens of this family and Berendt catalogues species of Corynetes, Opilo, and Tillus. A single species is found at Florissant.

6. Family **Malachidæ.**

Heer describes a Malachius from Oeningen, and this genus, Dasytes, and Ebæus have been found in amber.

7. Family **Lampyridæ.**

Heer states that three species of this family have been found in the Lias of Schambelen and one of Brodie's species from the Lower Lias of

Forthampton is referred by Giebel to Telephorus. In the Lower Purbecks of Durdlestone Bay Westwood figures a somewhat similar form under the name of *Telephorium abgarus*.

The family is moderately abundant in the Tertiaries and the species are all referred to existing genera. Telephorus claims nine described species from Oeningen, Rott, and Radoboj; Chauliognathus, Lampyris, and Luciola, one each from Florissant, Oeningen, and Rott, respectively. Lampyris is also stated to occur in amber, as are also Lycus and Malthinus.

8. Family Buprestidæ.

This family appeared as early as the Trias, a species of Glaphyroptera and one of Buprestites being described by Heer from Vadutz; the Rhaetic also has a species from Sweden referred to Buprestites. It was already abundant in the Lias, where no less than thirty-three species and seven genera were recognized by Heer at Schambelen; indeed, no other family contained half so many species, and it comprised more than 28 per cent. of all the Coleoptera. Two of the genera specified, Euchroma and Melanophila (2 sp.), are existing types, but Glaphyroptera (6 sp.), Micranthaxia (2 sp.), Buprestites, and Chrysobothrites are extinct types. A large proportion of these species are undescribed. A species of Buprestites is also recognized by Heer in the Lias of Pechgraben, Austria, and one is figured by Blake from the English Lias; four or five other Liassic species figured in Brodie's work are also referred to this family, some under the name of Ancylocheira. The Oölite of England furnishes several species, referred mostly to Agrilium, Buprestis, and Buprestidium, and consisting largely of single elytra, while in the Oölite of Solenhofen the genera Buprestis and Chrysobothris have been recognized.

Although abundant in Tertiary deposits, this family is not so predominating as its past history in the Mesozoic period would lead us to anticipate. It contains, however, a larger proportion than usual of generic types deemed extinct, Murray finding one, Lomatus, in the Tertiary deposits of Nágpur, in Central India, and Heer three, Protogenia, Füsslinia, and Buprestites, the last with three species, at Oeningen. Heer also finds species of this latter genus at Sieblos, Bovey Tracey, and in Greenland, and Giebel four others on the Rhine. Among modern genera we have Agrilus, single species described from Rott and others recognized at Creech and in amber; Acmæodera, two species at Oeningen; Sphenoptera, one species each at Oeningen and at Salzhausen; Chrysobothris, one species each at Stösschen and at Florissant; Anthaxia, seven species at Oeningen, Salzhausen, and Naumburg; Dicerca, five species at Oeningen, Salzhausen, Rott, and Naumburg; Perotis, five species at Oeningen, Rott, and Monte Bolca; Ancylocheira, ten species in the same localities; Buprestis, eight species in the Rhenish coal and British Columbia, besides unnamed species at Aix and in amber, both in the imago and the larval condition; Capnodis with three, Chalcophora with two, and Eurythyrea with one species, at Oeningen. Besides these, references have been made to the occurrence of unmentioned genera of the family in the Eocene of Bornemouth, Creech, and Dorset and in the peat of Lexden, in England, and a considerable portion of the beetles of Nágpur, in India, are referred here. They are rare in amber, Menge having but four specimens in his collection of over eight hundred Coleoptera. At Florissant, in Colorado, about thirty species have been found.

9. Family **Throscidæ.**

Heer figures *Trixagites floralis* from the Lias of Schambelen and Berendt catalogues Throscus from amber.

10. Family **Elateridæ.**

This family is abundant in Mesozoic rocks, commencing with the Lias, where, in Switzerland, ten species are recognized by Heer, some of which retain to some extent the coloration of the elytra. Megacentrus and Elaterites are the names given by Heer to the only two species he has figured, and the latter genus is also recognized by him in a species from the Jura of Irkutsk, Siberia. Roemer describes under the name of Elateropsis a species from the Rhaetic of Hildesheim, and the English Lias has furnished half a dozen species figured by Brodie and named by Giebel, all as of the genus Elater. Three species of Elater and one of Lacon are credited to the Solenhofen Oölite, and seven species of Elater and Elaterium to the English Purbecks.

The family was abundantly and variously represented in the Tertiaries, but the number of species referred to extinct genera is relatively small. Heyden describes Silicernius from Rott, Giebel Elaterium from Corfe, and to Elaterites are referred by Heer and Deichmüller four species from Oeningen, Greith, and Kutschlin; four species also are referred to Elater from Oeningen, Spitzbergen, and amber, and numerous references to the same genus are made from Aix, Utznach, Mundesley, Peckham, and Basel. Oeningen has besides furnished among the true *Elaterini* (to which it is probable all the foregoing refer), species of Diacanthus, Ischnodes, Corymbites, Cardiophorus, Lacon, Ampedos, Limonius, and Adelocera, of which genera Cardiophorus and Limonius are recognized in amber, and a species of Corymbites described from Wyoming. Oxygonus has two species in Utah, Cryptohypnus one in Wyoming, besides being recognized in amber, and Campsosternus one at Kutschlin. Among the *Eucnemini* we have only an Epiphanis from Utah and the genera Microrhagus and Eucnemis recognized in amber. Elateridæ of undetermined position have also been recognized at Florissant and in British Columbia and in amber. Menge had no less than one hundred and thirty specimens in his amber collection, and nearly as many are known from Florissant, including a great many species.

11. Family **Dascyllidæ.**

A minute species of Cyphon, figured by Brodie and named by Giebel, has been found in the Purbecks of England and recognized also by Geinitz in the Lias of Dobbertin.

The same genus has been recognized in the Prussian amber and in the Tertiaries of New South Wales. Scyrtes is also catalogued by Berendt from amber; the genus Ptilodactyloides was founded on a species also found in amber, and Atopa has been recognized at Aix.

6. Series CLAVICORNIA Latreille.

1. Family **Parnidæ.**

An elytron from the English Purbecks, referred doubtfully to Limnius by Brodie and described by Giebel as an Elmis, is the only reference to this family in the Mesozoic.

2. Family **Byrrhidæ.**

Five species of this family, of which three are named and two of these figured under the generic title Byrrhidium, have been recognized by Heer among the Lias insects of Schambelen.

Scarcely more than this is known of the family in Tertiary times. Three species of Byrrhus are described from Rott and Oeningen, and the same genus and Limnichus are recognized by Berendt among the insects found in amber.

3. Family **Lathridiidæ.**

A single species, *Lathridiites Schaumii* Heer, is found in the Lias of Schambelen.

In the Tertiaries Heer describes a Corticaria from Aix and Berendt specifies Lathridius in his catalogue of amber insects.

4. Family **Trogositidæ.**

Heer recognized four species of this family in the Liassic beds at Schambelen, but figures only one, for which he establishes a new genus, Cycloderma.

Trogosita is recorded by Serres at Aix, and nine species of the same are described from Oeningen, the Rhenish basin, and Greenland; two species of Peltis are also described from Oeningen and Rott, and Oeningen has furnished a species of Gymnochila.

5. Family **Nitidulidæ.**

Heer mentions seven species of this family as found in the Lias of Schambelen, but mentions specifically only *Nitidulites argoviensis* and *Petrorophus truncatus*.

They are not very abundant in the Tertiaries, considering the present extent of the family. Rhizophagus, Ips, Strongylus, and Nitidula are all said to occur in amber, and six species of Nitidula and two of Amphotis have been described from Radoboj and Oeningen. A species of Prometopia from British Columbia and one of Phenolia from Wyoming complete the list, excepting that half a dozen undescribed species of different genera are found at Florissant.

6. Family **Histeridæ.**

The only Mesozoic representative is an obscure specimen from Solenhofen, referred by Weyenbergh to Hister.

The same genus is represented at Oeningen by eight species; two species of Hister are found in amber, according to Menge, and half a dozen species of undetermined position occur at Florissant.

7. Family **Dermestidæ.**

This family has not been recognized below the Tertiaries, and is not abundant there, a single species of Attagenus having been described by Heyden from Salzhausen and one of Dermestes by Heer from Oeningen. Both Anthrenus and Dermestes are, however, said to occur in amber and two or three species of the family are found at Florissant.

8. Family **Mycetophagidæ.**

A single species referred to an extinct genus, Prototoma, is stated by Heer to occur in the Swiss Lias and a species of Triphyllus is described by Oustalet from Aix.

9. Family **Cryptophagidæ.**

Two species referred to an extinct type, Bellingera, figured by Heer from the Lias of Schambelen, represent this group in Pretertiary times.

The only Tertiary species known are an Atomaria from Oeningen, an Antherophagus from Wyoming, and a Cryptophagus said to occur in amber.

10. Family **Cucujidæ.**

Three species of Sylvanus and one of Passandra are said by Menge to occur in amber.

11. Family **Colydiidæ.**

A species of Cerylon described by Brodie from the English Purbecks is the only known Mesozoic species.

The Tertiary species are known only from amber, Stein describing two species of Bothrideres and Berendt cataloguing Colydrium.

12. Family **Erotylidæ.**

A species of Mycotretus is described by Scudder from Wyoming.

13. Family **Endomychidæ.**

In amber have been found a species of Lycoperdina, according to Menge, and Motschulsky figures a species under the new generic term Phymophoroides.

14. Family **Coccinellidæ.**

Either referred to Coccinella or simply to the family are two species from the upper Lias or lower Oölite of England, one in the middle Oölite of Solenhofen, and three or four in the upper Oölite of England.

In the Tertiaries we find a Lasia and a Sospita at Rott and twelve species of Coccinella about equally divided between Oeningen and Rott and in no case recognized in both localities. Coccinella has also been found in the Lexden peat and at Aix as well as in amber, where Menge records a larva. Scymnus is also recorded from amber and eight or ten species of the family occur at Florissant.

15. Family **Phalacridæ.**

Berendt catalogues a Phalacrus from amber.

16. Family **Scaphidiidæ.**

An obscure fossil from Solenhofen is described and figured by Weyenbergh as a Scaphidium.

In the Tertiaries Heyden figures a new genus, Seniaulus, from Rott. Heer describes a Scaphisoma and a Scaphidium from Oeningen and the latter genus is recognized in amber.

17. Family **Staphylinidæ.**

Brodie figures two rove-beetles from the English Purbecks, which Giebel describes under the genera Philonthus and Prognatha, respectively; these appear to be the only Pretertiary members of the family.

In Tertiary times, however, the family was abundant and had a varied representation, though all the generic types but two or three are recognized as still existing. One of the extinct genera, Protactus Heer, with two species, was thought by him to represent a new subfamily group, *Protactidæ*, whose nearest relations were with the *Homalini*. Of this latter type we have a species of Anthophagus from Rott and a Homalium from Radoboj, while both genera are said to occur in amber. Of the *Oxytelini* we have two species of Bledius from Oeningen and Wyoming and two of Oxyporus from Oeningen and Rott, besides both of these from amber, and from Oeningen and Utah two species of Oxytelus, a genus recognized by Moore in the Tertiaries of New South Wales. The

Tachyporini are represented by a single described species of Tachyporus from Rott, though not only this genus but Tachinus and Mycetoporus occur in amber, the first-mentioned abundantly. Of the *Pæderini*, Oustalet describes two species of an extinct genus which he calls Erinnys[1] from Aix, a locality which has also furnished one species each of Achenium, Lithocaris, and Lathrobium; the last-named genus has also species described from Oeningen and Wyoming, and, besides, Heyden has described a Sunius from Rott and Berendt recognized a Stilicus from amber. The *Stenini* are represented by three species of Stenus from Aix and Rott, and it has also been found in amber. Of the *Staphylinini*, there are Quedius with two species at Aix and Philonthus with three at Aix and Rott (both of these genera being recognized also in amber), Xantholinus at Aix, Leistotrophus in Utah, Staphylinites in Wyoming, and eight species of Staphylinus at Aix and Oeningen; this last genus has also been recognized in both Prussian and Sicilian amber, on the Isle of Wight, at Rott, and in Italy. Finally, of the *Aleocharini*, Myrmedonia and Aleochara have been recognized in amber, a species of Hygronoma has been described from Aix, and one of Gyrophæna from Utah. Nearly thirty species of the family have been found at Florissant, but are not yet published.

18. Family **Pselaphidæ**.

We know this family in a fossil state only from amber inclusions. Motschulsky recognized two genera, which from their relation to living forms he called Eupsinoides and Tmesiphoroides. Berendt notes there the presence of Bryaxis, Euplectes, and Pselaphus, and Menge that of Bythinus.

19. Family **Paussidæ**.

Menge mentions the occurrence of Paussus in amber. Motschulsky figures from Menge's collection a species which he recognizes as a distinct type, Paussoides, and Stein describes an Arthropterus from the same.

20. Family **Scydmænidæ**.

Oustalet describes a Scydmænus from Aix, Berendt recognizes the same genus in amber, and Motschulsky mentions as found in amber a distinct type, Scydmænoides.

21. Family **Silphidæ**.

An obscure Solenhofen fossil is figured by Weyenbergh as a Silpha. Besides this the only Mesozoic form is a fragment from the Cretaceous of Kounič, referred by Frič to Silphites.

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[1] This name is preoccupied in Lepidoptera (Schrank, 1801). It may be called Lithoplanes (λίθος, πλάνης).

The family is poorly represented in the Tertiaries. Anisotoma and Catops are credited to amber and four species of Silpha are described from as many localities: Oeningen, Radoboj, the Rhine, and Spitzbergen. Besides these Heer has recognized the recent *S. dispar* Herbst in the glacial clays of Schwerzenbach. Two other species of the family have been found in a single example, each, at Florissant.

22. Family **Hydrophilidæ**.

This family was abundantly represented in Mesozoic times. Its first recognition is in the Rhaetic, Heer describing a specimen of Hydrophilites from Sweden. In the Lias of Switzerland no less than fifteen species have been recognized by Heer, where, next to the Buprestidæ, they are the most abundant of beetles at Schambelen. Only a few of the species have been described or figured by Heer, but these have all been referred to extinct genera: Hydrophilites (3 sp.), Wollastonites, and Hydrobiites. The English Lias has also furnished a species referred by Giebel to Berosus, and the Purbecks of the same country several species figured by Brodie and referred by Giebel to Helophorus (2 sp.), Hydrophilus (2 sp.), and Hydrobius, besides some unnamed forms. Weyenbergh also looks upon the *Scarabæides deperditus* of Germar, from the Oölite of Solenhofen, as a Hydrophilus, but it is rather a Belostoma. (See p. 61.)

The family is equally well represented in Tertiary times. A species of Cercyon from British Columbia represents alone the *Sphæridini*. Of the *Hydrobiini*, an extinct genus Escheria, with two species, is described by Heer from Oeningen, and has, perhaps, another on the Rhine; two species of Berosus are known from Wyoming, four of Laccobius from Aix, Corent, Rott, and Wyoming, two of Philhydrus from the last, and six of Hydrobius from Oeningen, Aix, Spitzbergen, and Wyoming. The *Hydrophilini* are the most abundant, showing two species of Tropisternus from Wyoming, six of Hydrous from Oeningen and Rott, and eleven of Hydrophilus from Aix, Parschlug, Chexbres, and Oeningen, besides the interglacial beds near Basel. *Hydrophilus piceus* L. has also been recognized by Sordelli in Italian peat, and the genus has been recognized at Florissant and in the Isle of Wight. Heer also describes two extinct genera, Hydrophilites and Hydrophilopsis, the former with a species from Greenland, the second with one from Oeningen, to which Oustalet adds a second from Aix. The *Helophorini* are represented by two species of Helophorus from Oeningen and one of Ochthebius at Rott.

7. Series ADEPHAGA Clairville.

1. Family **Gyrinidæ**.

The Lias furnishes a considerable number of species of this family, Heer finding seven in Switzerland and two being known from England. Heer refers all his species to Gyrinites and Gyrinus, but only figures four of them, all but one Gyrinites. The two English species are both figured by Brodie and named Gyrinus by Giebel. The only other Mesozoic form known is a Gyrinus from Solenhofen.

They are not so abundant in the Tertiaries, the only extinct species known being three of Dineutes from Oeningen and one from amber referred by Motschulsky to a distinct genus Gyrinoides. Gyrinus is also recognized by Menge in amber and the modern *G. natator* L. and *G. marinus* Gyll. were found by Heer in the glacial clays of Switzerland at Schwerzenbach and Basel.

2. Family **Dytiscidæ**.

This family has not been recognized in the Swiss Lias, but the English has furnished a single species referred to Laccophilus. The Oölite of Bavaria and that of England each possesses a species of Dytiscus and one of Hydroporus.

It is tolerably abundant in the Tertiaries, but all the species have been referred to existing genera. Cybister is represented by three species at Oeningen and Locle, Eunectes by one at Corent, Hydaticus by two at Oeningen, Dytiscus by six at Oeningen and Höhgau in Miocene beds, and at Merla, Italy, in the Quaternary, besides which the genus has been recognized in the Isle of Wight Tertiaries, on the Rhine, and at Aix. Heer describes two species of Colymbetes, from Oeningen and Radoboj, and one is recognized at Aix by Hope; Heyden describes an Agabus from Rott and Menge says it occurs in amber, while Aymard quotes two species of Necticus as found at Le Puy. Heer again describes two species of Hydroporus from Oeningen and a Laccophilus from Spitzbergen, and the latter genus has been recognized in Utah. Heyden describes a Pelobius from Rott.

3. Family **Carabidæ**.

This family is one of the most abundant in species, whether in Mesozoic, Tertiary, or present times. It reaches back to the Rhaetic, Heer having found one species among those of Sweden examined by him, which he refers to the extinct genus Carabites. In the Lias they are more plentiful, Heer having found eleven species at Schambelen, although he has only named and figured four, of which he refers three to Carabites and one to the extinct genus Thurmannia. One of the species of Carabites has also been recognized at Dobbertin, and an additional species in the Austrian Lias. Three species in the English Lias figured by Brodie are referred by Giebel to Harpalus. The Oölites have furnished a greater variety of forms, a dozen species from the English Purbecks having been referred by Giebel to Carabus, Harpalus, Cymindis, and Camptodontus, and by Westwood to Harpalidium; one species of Carabus also is found in the lower Oölite of England, and species referred to Carabus and Carabicina have been found in the middle Oölite of Solenhofen. Lastly, Frič figures under the name of Brachinites a fragment of an elytron from the Cretaceous of Bohemia. (See p. 106, note.)

In the Tertiaries this family is very abundant and varied, especially among the *Harpalinæ*. In the *Harpalini* proper, Harpalus has eleven species from Rott, Aix, Oeningen, and Radoboj, besides the recent *H. lævicollis* in the glacial clays of Schwerzenbach and others reported from amber and the Pliocene of Mundesley; Heer describes also one species each of Sinis and Dichirotricus from Oeningen. Of the *Chlæniini* we have only the genus Chlænius, two species of which are known, one from amber and the other from the bone caves of Pennsylvania. Of the *Brachynini*, a single species of Brachynus from Oeningen. Of the *Helluonini*, a species of Polystichus from Aix, another reported in amber, and one of Helluomorpha described from the same. The *Lebiini* are more varied and abundant: Motschulsky has credited two extinct genera, Agatoides and Cymindoides, to amber, besides which Dromius and Cymindis are reported from the same; species of Cymindis are also described from Oeningen and the Pennsylvania bone caves, and of Lebia from Salzhausen. Among the *Platynini*, a species of Platynus has been found in Wyoming, another in the Quaternary beds of La Boisse, and a recent species, *P. gracilis* Gyll., in the Pleistocene of Jarville. Heer has found an Anchomenus at Radoboj and Menge recognizes it in amber, which also harbors Calathus. Of the *Licinini*, five species of Badister occur at Oeningen, Horn finds two of Dicælus in the Quaternary bone caves of Pennsylvania, and Wollaston recognizes Licinus in the Lexden peat. The *Pterostichini* are still more varied: three species of Pterostichus are known from Oeningen and the peat of Wohlscheid, and it has also been noticed in amber and in the Pennsylvania bone caves; two species of Argutor are described from Oeningen, and a recent species, *A. vernalis*, in the interglacial clays near Basel; another recent species, *Omaseus nigrita*, occurs in similar beds at Dürnten; two species of Feronia are described from Aix and one is said to occur in the Pleistocene of Utznach; four species of Amara occur at Oeningen and Hochheim, one of Stomis at Aix, and a Loxandrus in the glacial clays near Toronto, Canada. Among the *Pogonini* we have two species of the extinct genus Trechinites at Oeningen. Motschulsky recognizes another extinct type, Trechoides, in amber, and Fliche finds the recent *Patrobus excavatus* in the Pleistocene of Jarville. Of the *Bembidiini* only Bembidium has been found, but of it four species, in amber, in Wyoming, and at Aix, besides the recent species, *B. nitidulum* and *B. obtusum*, in peat at Jarville. A species of Panagæus, found at Aix, represents alone the *Panagæini*. When we come to the *Carabinæ* proper we find among the *Scaritini* an interesting extinct type, Glenopterus Heer, represented by a single species at Oeningen; Heer also describes a Scarites from Radoboj and Clivina occurs in amber. The *Nebriini* are represented by Nebria, which has one species each at Oeningen, Aix, and in British Columbia, and has been detected also in amber. A single

Loricera from the glacial clays of Toronto, Canada, represents the *Loricerini*, and three species of Cychrus, described from the Pennsylvania bone caves and from Wyoming, the *Cychrini;* while for the *Carabini* no less than ten species of Calosoma are described from Aix, Oeningen, Locle, and the Rhine, eight species of Carabites from the polar regions, Oeningen, and Dürnten, and a recent species of Carabus, *C. arvensis*, is found at Schwerzenbach; the genus has also been recognized in amber. Other undetermined species of Carabidæ have been reported from Antrim and Hérault, and some thirty species occur at Florissant.

4. Family Cicindelidæ.

Brullé reports a species of Cicindela in amber.

C.—METABOLA Packard (ex Leach).

Body generally small, cylindrical, distinctly triregional, and well constructed for swift or directed flight. Thorax highly organized and compact, the prothorax insignificant, the abdomen generally pedunculate. Mouth parts haustellate. Front wings membranous, generally larger, often much larger, than the hind pair, the veins generally distant and the membrane without reticulation. Metamorphosis complete; pupa inactive.

5. Order DIPTERA Linné.

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(See, also, pp. 82 and 86.)

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Body generally small, subcylindrical, sometimes flattened above, completely triregional, the head especially being connected with the thorax by a very constricted neck, the integument delicately coriaceous. Antennæ either long, filiform, and generally simple, or short, with the third joint inflated and the remainder reduced to two or three tapering joints or a bristle. Mouth parts adapted for piercing and sucking, the greatly developed fleshly labium (which is destitute of palpi) serving as a gutter for the reception of the lancet-like maxillæ and mandibles. Prothorax reduced to at most a mere collar on the front of the mesothorax, which latter is developed at the expense of both the other parts of this region. Front wings membranous, never folded, generally slender, with an inferior basal lobe, the veins in front crowded, behind distant, the cross-veins few and definitely placed; no reticulation. Hind wings reduced to a club-shaped lamina. Legs very slender. Metamorphosis complete, the appendages of the pupa free, but the whole pupa often undergoing its transformation within the larval skin. These metamorphoses are characterized as orthorhaphic when the pupa escapes by a T-shaped vent in the larval skin and cyclorhaphic when it escapes through a circular opening forming a lid. Corresponding exactly to this and to structural distinctions in the wings, the larva, which is apodal or vermiform, is either acephalous, the first segment never being chitinous (Cyclorhapha), or has a more or less perfectly developed head (Orthorhapha).

1. Division DIPTERA CYCLORHAPHA Brauer.

The only Mesozoic species (excepting a couple of Syrphidæ) referred to this division of the Diptera, and possibly belonging here, is *Musca lithophila* from Solenhofen, an object so obscure that it is not even certainly a Dipteron.

In the Tertiary rocks this division is much more rare than the other Diptera, and, with the exception of the Syrphidæ, may be treated as a whole.

Four species of Musca, using the term in a broad sense, are described by Presl from amber, and Schlotheim, Burmeister, and Gravenhorst also refer to it in the same way. Larvæ of this division, under the names of Musca and Muscidites, are described from Utah and from the Rhine. A vast host of undetermined genera of several of the families occurs at Florissant. Our present knowledge, however, is largely dependent upon amber. To take the series of families in their natural order, we may begin with the *Phoridæ*, where Loew has recognized eleven species of Phora in amber, some of them differing greatly from modern forms; of the *Agromyzidæ*, a species of Agromyza has been found at Radoboj and a larval mine on Ulmus at Schossnitz has been referred to the same genus by Göppert; of the *Oscinidæ*, Chlorops occurs in amber; of the *Drosophilidæ*, Drosophila, in amber; of the *Ephydridæ*, Ochtera at Aix and Ephydra in amber; of the *Sapromyzidæ*, Sapromyza in amber; of the *Lonchæidæ*, one species each of Palloptera and Lonchæa, described from British Columbia; of the *Trypetidæ*, one species of Tephoritis from Radoboj; of the *Ortalidæ*, an extinct genus Lithortalis from British Columbia (eight or ten species of this or the preceding family occur at Florissant); of the *Micropezidæ*, Calobata (two species) in amber; of the *Psilidæ*, an extinct genus Psilites described from Radoboj; of the *Sciomyzidæ*, three species of Sciomyza described from British Columbia; of the *Helomyzidæ*, two species of Heteromyza described, one from Utah and one from Wyoming, and Helomyza recognized in amber; of the *Cordyluridæ*, Scatophaga in amber, Cordylura at Radoboj; perhaps also Heer's *Dipterites obsoletum* belongs here (Massalongo's *Dipterites Angelinii* from Monte Bolca is quite unintelligible); of the *Anthomyidæ*, six species of Anthomyia described from Radoboj, Rott, and British Columbia, besides which Anthomyia and Eriphia have been found in amber and species of undetermined genera occur at Florissant; of the *Muscidæ*, Stomoxys is referred to by Giebel as occurring in the Tertiary (without specification) and Loew recognizes the family in amber; of the *Tachinidæ*, Tachina, Echinomyia, and undetermined genera in amber, and a species of Echinomyia described from Oeningen; of *Œstridæ*, Œstrus in amber and at Florissant, with possibly the larva from Oeningen described by Heer under the name of *Dipterites obovatum;* of *Pipunculidæ*, Pipunculus in amber and half a dozen species of the family at Florissant; of *Conopidæ*, an extinct genus, Poliomyia, has been found in Wyoming, and a second, unnamed, has been briefly characterized by Loew from amber.

Family **Syrphidæ.**

A very obscure object from Solenhofen is referred by Weyenbergh to Cheilosia, and Giebel refers to a new genus, Remalia, a minute fly figured by Brodie from the English Purbecks, but its reference here is very doubtful.

In the Tertiaries this family is more abundant and varied than any of the other families of Diptera cyclorhapha. Burmeister and Serres both recognize Microdon at Aix, Pipiza has been described from Rott, Cheilosia from Wyoming, and seven species of Syrphus from Oeningen, Radoboj, Rott, and Sinigaglia, besides which it has been recognized in amber. In amber, also, are found two peculiar genera allied to Oscia and Xylota, besides Cheilosia, Volucella, and Criorrhina; Rhingia is noticed at Aix, Eristalis described from Utah, Helophilus and Merodon from the Rhine, and Milesia from Wyoming. Lastly some thirty or more species of various genera occur at Florissant, a considerable number of them in a remarkable state of preservation.

2. Division DIPTERA ORTHORHAPHA Brauer.

1. Section BRACHYCERA Zetterstedt.

1. Family **Dolichopodidæ.**

This family is particularly abundant in amber, Loew having counted not less than sixty-eight species of the genera Dolichopus, Rhaphium, Porphyrops, Psilopus, Medeterus, and Chrysotus. Giebel describes a single species each of Medeterus and Chrysotus from amber, and the genus Dolichopus has been recognized at Sieblos and in Wyoming and British Columbia.

2. Family **Empidæ**.

Weyenbergh figures a fly from Solenhofen under the name of *Empidia Wulpii* and a species from the Wealden of England figured by Brodie is referred by Giebel to a new genus, Hasmona.

All but one of the twelve genera which have been recognized from the Tertiaries are known from amber. Of the *Tachydromina* we have three species of Hemerodromia, five of Tachypeza, seven of Tachydromia, and one of Drapetis recognized by Loew in amber. Of the *Empidina* proper, Loew found twenty-one species of Rhamphomyia, sixteen of Empis, three of Leptopeza, three of Gloma, and two of a genus near Hilara, all from amber; besides which Giebel describes two species of Empis from amber and two are described from the Rhenish coal; the genus has been recognized also at Aix and Heer describes an extinct genus, Hilarites, from that place. Of the *Hybotina* all again are amber species, Loew recording two species of Hybos and one of Brachystoma, while Giebel describes a species of Thirza.

3. Family **Cyrtidæ**.

A species of Acrocera is described from Utah.

4. Family **Therevidæ**.

One species of Thereva is described from the Rhine and three were recognized by Loew in amber.

5. Family **Bombylidæ**.

The only species known to Loew from amber was a Corsomyia, but Giebel describes a Lomatia and Burmeister mentions an Anthrax from the same. Anthrax is also said to occur at Oeningen and on the Rhine and Germar describes an Anthracida and a Phthiria from the Rhine. Berendt also recognized Bombylius in amber and Schlotheim says it occurs at Oeningen. Florissant has a great variety of forms of this family, though the species are rare in individuals.

6. Family **Nemestrinidæ**.

Serres mentions a Nemestrina at Aix, and a new genus, Palembolus, is described from Florissant, which has, besides, several other species belonging to this family or to Midaidæ.

7. Family **Asilidæ.**

This family is represented in the Mesozoic rocks by an insect in the Lower Lias of Forthampton, Eng., referred by Brodie to Asilus, and by one from the Oölite of Solenhofen, called Asilicus by Germar.

In the Tertiaries we have five species of Asilus described from amber, Oeningen, and Radoboj, besides which it is reported from Aix and Rott; of the section *Dasypogonina* there is an extinct genus, Stenocinclis, found in Wyoming. Holopogon has an amber species and Leptogaster one at Radoboj; Dasypogon also is reported as found in both Prussian and Sicilian amber. This family and the following are abundantly represented at Florissant, and the former also occurs in British Columbia, and, according to the author of the Ittiologia Veronese, in Italy.

8. Family **Leptidæ.**

Atherix and Leptis are the only genera of this family described as fossil; of the former four species were known to Loew from amber, of the latter five, and, besides this, it has been recognized by F. Smith in the Eocene deposits of the Isle of Wight.

9. Family **Tabanidæ.**

This family is rare in a fossil state. Loew found but a single specimen in amber, belonging to Silvius, and it has not been otherwise reported from that source. Heer figures a species of Hexatoma from Oeningen. Aymard referred an undescribed species from Le Puy to a distinct genus, Æmoaipus. Tabanus has been reported to occur in the Rhenish coal and at Aix and Malfatti finds a specimen referred to this family in the calcareous tufa of the Quaternary of Grone, Italy.

10. Family **Acanthomeridæ.**

A single specimen of a species of Arthropeas was found by Loew in amber.

11. Family **Stratiomyidæ.**

The larger part of the fossil species of this family have been recognized at Aix, where Giebel describes a new genus, Curtisimyia, and Hope figures an Odontomyia. Serres also recognized there species of Nemotelus, Oxycera, and Sargus. In addition to these, Oustalet describes a species of Stratiomys from the Miocene of Pontary, and the same genus has been recognized in larvæ at Bernouville (Quaternary) and at Rott, and Beris by Giebel at an unmentioned Tertiary locality. At Florissant there are a half dozen species of different genera.

12. Family **Xylophagidæ.**

Loew found in amber a large species of Xylophagus, two species of a new genus (Bolbomyia), one species of still another extinct genus (Habrosoma), and one species each of Electra and Chrysothemis; most of them are known by single examples. Heer also describes a Xylophagus from Aix, where Serres had already recognized its presence.

2. Section NEMATOCERA Latreille.

1. Family **Rhyphidæ**.

A very fragmentary fossil from the English Purbecks is figured by Brodie under the name of *Rhyphus priscus*, but is referred by Giebel to a special genus, Bria. It is doubtful whether it belongs here; it is indeed more probably a Chironomid.

The family is recognized in Tertiary times by four species of Rhyphus credited by Loew to amber, by the occurrence of the same genus in Sicilian amber according to Guérin, and by a species of the same described by Heer from Radoboj.

2. Family **Tipulidæ**.

Several species of Tipulidæ are referred to by Brodie, Westwood, Buckman, and Murchison as found in the Lias and Purbecks of England, but in some instances where they are figured they certainly belong to other families of Nematocera. One doubtful species, called *Tipularia Teyleri*, has been recognized by Weyenbergh in the Oölite of Solenhofen.

In the Tertiary beds no family of Diptera has attained such variety, although the number of individuals found has not been so large as, for instance, in the Bibionidæ. It is also peculiarly rich in extinct genera.

Of the Tipulidæ with short palpi we have a large number recognized by Loew in amber; such are: Rhamphidia, 4 sp.; Elephantomyia, 3 sp.; Cylindrotoma, 4 sp.; Trichocera, 2 sp.; Eriocera, 2 sp.; and Erioptera, 14 sp.; besides the following extinct genera peculiar to amber: Trichoneura, 3 sp.; Calobamon, 1 sp.; Haploneura, 4 sp.; Critoneura, 2 sp.; Tanymera, 4 sp.; Tanysphyra, 1 sp.; Ataracta, 8 sp.; and Styringomyia, a genus also found in copal, 1 sp.; in addition Giebel describes two species of Limnobia in amber and it has been recognized by a dozen other species at Radoboj, Aix, Oeningen, and on the Rhine; Erioptera also has one species at Rott and Trichocera one at Aix; in addition to which we have, of genera not represented in amber, a Rhipidia at Radoboj and three species of Dicranomyia in Utah; Utah also furnishes three extinct genera, Cyttaromyia, Spiladomyia, and Pronophlebia, with one species each. At least fifteen or twenty species of this group have been found at Florissant.

Of the other Tipulidæ Loew found in amber sixteen species of Tipula, one of Macrochile, and four of Dixa; Berendt reports also Adetus. Tipula has also been found abundantly in other places, about eleven species having been described from Radoboj, Aix, Krottensee, Italy, and Utah, besides having been mentioned from Sicilian amber and as a larva at Sieblos. Nephrotoma has also been credited to Aix by Serres, Ctenophora described from Rott, and Ptychoptera from Krottensee. This division has been found in still greater abundance than the other at Florissant and is even richer in individuals. The family is also recognized by H. Woodward in the Eocene deposits of the Isle of Wight and Aymard records two species of an extinct genus at Le Puy.

3. Family **Psychodidæ.**

This family is known in a fossil state only from amber, in which Loew has found eighteen species, a number which he thinks may be reduced by more abundant material. Six species of the existing genus Psychoda are recognized, while the other genera are all peculiar to amber, Phalænomyia with nine species, Diploneura with two, and Posthon with one species. Psychoda was also recorded among amber inclusions by Burmeister.

4. Family **Chironomidæ.**

One would scarcely expect the delicate, minute flies of this family to be preserved from Mesozoic times, yet they seem to be not altogether unknown. Two species referred to Macropeza are figured, one by Geinitz from the Lias of Dobbertin and one by Brodie from the English Purbecks; two other obscure forms from the English Purbecks are figured under the name of Chironomus; and *Corethrium pertinax* and *Cecidomium grandævum* of Westwood, from the same beds, appear to belong to this family rather than to the Cecidomyidæ or Culicidæ. *Rhyphus priscus* Brodie, from the English Purbecks, also probably belongs here and not to the Rhyphidæ.

The family is very abundant in amber, Loew having found seven species of Tanypus, more than forty of Chironomus, and twenty-six of Ceratopogon. Giebel also describes two species of Chironomus and one of Ceratopogon from amber, and these genera had previously been recognized as occurring there by Burmeister, Erichson, and others. Duisberg also records a peculiar genus, Sendelia, from the same. But the occurrence of the family in a fossil state is not confined to amber: thirteen species of Chironomus have been described from Rott, Oeningen, Radoboj, and Utah, and the genus has been recognized also in Wyoming, while numerous pupæ distinguishable as belonging to several species are recorded by Heyden from Rott. Ceratopogon has also a species at Rott, and it has been recognized at Aix and in Sicilian amber. Numerous specimens of the family occur at Florissant, but they are usually in very poor condition; they have also occurred in the British Columbia Tertiaries.

5. Family **Culicidæ.**

The English Purbecks have furnished two species which have been referred to this family, one a very obscure object, called *Tanypus dubius* by Brodie, but referred to a new genus, Asuba, by Giebel; the other, a wingless specimen, but with antennæ and legs preserved, called *Culex fossilis* by Brodie.

The only members of this family found by Loew in amber are a species of Mochlonyx and one of Culex; Giebel also describes a species of Culex from amber and species have been described from Rott and from Utah. Heyden also describes another species from Rott, under the name of Culicites, a Corethra is described from Utah, and one is mentioned from Aix. Two or three species only of this family in single examples are found at Florissant and it has been recognized in the Isle of Wight Tertiaries.

6. Family **Bibionidæ**.

Although species supposed to belong to this family have been reported from Mesozoic rocks, it is doubtful whether it is yet recognizable before Tertiary times. *Protomyia dubia*, figured by Geinitz from the Lias of Dobbertin, is certainly not a Dipteron at all.

In Tertiary times, however, they are among the commonest of insects, as far as individuals go, though they are not correspondingly rich in species, and in amber they are comparatively rare, the genera most abundant in the rocks being almost or altogether absent. The species found by Loew in amber are one of Dilophus, two of Plecia, and three of Scatopse. Bibio is also reported from amber by Guérin, Serres, and Burmeister, but they probably mistook some other genera for Bibio or used the term in the broad sense of the family, since Loew says it "appears strangely enough to be altogether wanting." Of these genera, Dilophus and Plecia[1] occur in the rocks, the former in a single species at Rott and indicated only at Aix (Serres), the latter in considerable abundance, for over twenty species are described from Oeningen, Radoboj, Aix, Rott, Parschlug, Corent, Auvergne, Krottensee, Wyoming, and British Columbia, while an allied extinct genus, Epiplecia Giard, occurs at Corent; Bibio is even more numerous, over forty species having been described from Oeningen, Rott, Corent, Aix, Radoboj, Wilhelmsfund, Krottensee, Tállya, Felek (near Klausenburg), and Monte Bolca; and Bibiopsis,[1] an allied extinct genus, has five species from Salzhausen, Krottensee, Aix, and Rott. Another extinct genus, Protomyia,[1] has nearly forty species at Oeningen, Aix, Krottensee, Corent, and Rott, while Penthetria has four species at Radoboj and Corent, besides being recognized at Aix and Krottensee. Fully one thousand specimens of this family have been found at Florissant, but the species are not correspondingly numerous, being apparently but fifteen or twenty in number.

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[1] The species first referred to Protomyia and Bibiopsis by Heer, who founded the genera, are not included under these names in this enumeration, since Loew considered them all to belong to Plecia and the genera as without foundation. Those since published have not been critically examined. *Penthetria similkameena* Scudd., from British Columbia, is a Plecia.

7. Family Simulidæ.

The Purbecks of England furnish two species, *Simulium humidum* Brod. and *Simulidium priscum* Westw., apparently belonging to this family.

In the Tertiaries the genus Simulium has been recognized in a species described from Rott by Heyden, in six species recorded by Loew from amber, and in one found by Guérin in Sicilian amber.

8. Family Mycetophilidæ.

In the Mesozoic this family is represented only in the English Purbecks. Here we recognize species figured by Brodie under the genera Platyura, Macrocera, and Sciophila, and credited by Giebel to new genera, Adonia, Sama, and Thimna, respectively; also a second Sciophila, which is very obscure, and a species figured by Westwood, which Giebel refers to an extinct genus, Thiras.

In the Tertiaries this family is one of the best represented and is abundant in generic types, though, as compared to the Tipulidæ, few of these are extinct. The greater number have been found in amber, and, as in the Bibionidæ, such as have been found in the rocks belong generally to genera distinct from those occurring in amber. The following genera have been found in amber by Loew: Zygoneura, 1 sp.; Sciara, 21 sp.; Mycetophila, 23 sp.; Leja, 26 sp.; Sciophila, 15 sp., besides 3 described by Giebel; Sciobia, 19 sp.; Platyura, 16 sp.; Macrocera, 6 sp.; Heterotricha, 1 sp.; Dianepsia, 2 sp.; Mycetobia, 5 sp.; Aclada, 2 sp., and Diadocidia, 1 sp. Boletophila is also reported in amber by Burmeister and four of the genera mentioned above have been found in the rocks, viz: Sciara, of which twelve species have been described, from Aix, Radoboj, Oeningen, Rott, Krottensee, and British Columbia, besides mention of several other species at these same places; Mycetophila, fifteen species, from Radoboj, Aix, Oeningen, and Utah, besides other unnamed species from Aix and Auvergne; Sciophila, one from Parschlug; and Diadocidia, one from Green River. Of the genera above mentioned, four are peculiar to amber, Sciobia, Heterotricha, Dianepsia, and Aclada; and an extinct genus, Sackenia, has been found in Utah. Further than this, five species of Cordyla and one of Boletina are known from Rott, two of Brachypeza, one of Trichonta, and one of Boletina from British Columbia, and one of Gnoriste from Utah, the last being also indicated from Aix. Species of undetermined genera have also been reported from Sicilian amber, Rott, Wyoming, and Florissant, in the last of which more than thirty species have been found.

9. Family Cecidomyidæ.

Our knowledge of this family also is largely due to amber. In the *Anaretina* the only genus found by Loew is Campylomyza, of which he records five species. An extinct genus, Lithomyza, is, however, described from Utah, apparently belonging to this section. Of the *Cecidomyina*, Loew found the extinct genus Monodiciana, with one species in amber, together with eighteen species of Cecidomyia, distributed among the subgenera Diplosis, Cecidomyia, Dirhiza, Epidosis, and Synapta. Lasioptera was also recognized in amber by Burmeister and has been described from Wyoming, while three species of Cecidomyia have been described from Oeningen, Rott, and Aix, and recognized also in Sicilian amber.

6. Order **LEPIDOPTERA** Linné.

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(See, also, pp. 32 and 36.)

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Body cylindrical, elongated, completely triregional, the integument delicately coriaceous. Antennæ long, filiform, and, excepting sometimes for regular, lateral, laminate outgrowths, simple. Mouth-parts arranged for sucking, the greatly elongated maxillæ forming a hollow canal by the union of their channeled inner surfaces and capable of rolling up like a watch spring between the appendages of the labium; mandibles aborted. Pronotum insignificant, but distinct from the compact thorax, which is composed subequally of the other two joints. Wings subequal; generally very large, membranous, the hinder pair sometimes folded slightly at the inner edge, covered on both surfaces with imbricated and colored scales, often forming patterns of exquisite beauty; the neuration simple, the marginal vein absent, the scapular and externomedian united or approximated in the middle of the wing forming between them a median cell and furnishing almost all the subordinate branches; cross-veins almost wholly wanting; no reticulation. Legs very slender. Metamorphosis complete; the appendages of the pupa soldered to the body. Larva eruciform. Habits terrestrial, but many larvæ endophytophagous, and the pupæ generally concealed or inclosed in a loosely-woven cocoon.

The fossil forms of this order are so rare that they may be treated here in a single paragraph. All such as have been credited to Carboniferous deposits have been shown to belong to other groups. The Mesozoic forms are exceedingly few. The mines of Tineidæ or allied moths have been noticed by Fritsch in leaves from the Cretaceous of Bohemia and by Hagen in some from the Dakota group of Nebraska. *Tineites lithophilus* Germ., from the Oölite of Eichstatt, is, according to Heer and Hagen, a Termes. Two Sphingidæ, *Sphinx Snelleni* and *Pseudosirex Darwini*, have been described by Weyenbergh from the Oölite of Solenhofen. The former is represented by a very characteristic fossil in which the spiral tongue appears; the latter, by a far more obscure wing.

In the Tertiaries these insects are more common, but still among the greatest rarities. All the larger groups, however, are represented. Among the *Microlepidoptera* the *Tineidæ* are not rare in amber, Menge having sixty-nine specimens in his collection, of which one was a caterpillar and two were pupæ, but they have not been studied. Gravenhorst also mentions a Tinea in amber and Presl describes one species. Germar figures an Ypsolophus from Bonn and Heyden the larval mine of a Nepticula from Rott. Kawall also describes a Tineites from Bergkrystall at Ufalei, in Siberia. The *Tortricidæ*, too, occur in amber, Menge having fifteen moths, seven larvæ, and four pupæ of several species. The *Pyralidæ* are represented by a single specimen from Aix, which Heer describes under the name of Pyralites. Of the *Phalænidæ*, Heer describes two species referred to Phalænites from Radoboj and mentions one from Aix, and Curtis mentions one from the latter place, which, however, he says may be a noctuid. Giebel also describes an Angerona from amber, on the wing of which he noted two specimens of a species of Chelifer. Of the *Noctuidæ*, four species, some of them exceedingly obscure, have been described under the name Noctuites, two from Radoboj, one from Aix, and one from Auvergne. *Bombycidæ* are more numerous. Two species of Bombycites are figured by Heer from Oeningen, together with the larval sac of a species of Psyche. The latter group has been recognized in the same way in amber, Menge mentioning fifteen larval sacs of seven different kinds. A species of Lithosia is said to be found at the Isle of Wight and Serres refers species at Aix to Bombyx or Cossus and to Zygæna. Of the *Sphingidæ*, Berendt says that a Sphinx occurs in amber and Serres refers to two species of Sesia at Aix. The *Rhopalocera* are first known to us in the Tertiaries, all references to their earlier appearances having been shown to be erroneous, and more than a dozen species are recorded, belonging to as many genera, most of the latter extinct. Of the existing genera we have only two, a Pontia and a Eugonia at Radoboj, which also furnishes a species of Mylothrites. Aix furnishes the largest number (5), Pamphilites, Thaites, Coliates, Lethites, and Neorinopis, besides a larva described by Daudet under the name Satyrites; Florissant, the next largest (3), Prodryas, Jupiteria, and Lithopsyche, all nearly related, besides one or two other undetermined forms. Rott gives us Thanatites, and a second species is reported from the same place, but not yet described. According to Gravenhorst, the larva of a Lycæna occurs in amber. Finally, Procaccini Ricci states that Lepidoptera have been found at Sinigaglia.[1]

7. Order HYMENOPTERA Linné.

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Body completely triregional, subcylindrical, the abdomen sometimes depressed or compressed, both head and abdomen generally connected with the thorax by a constricted neck, the integument subcorneous. Antennæ simple, filiform. Ocelli generally present. Mouth-parts arranged for lapping, in which the highly-developed and greatly-elongated labium and its appendages perform the principal part, ensheathed loosely by the maxillæ; the mandibles are also well developed, but principally as weapons or tools in the economy of the insect. Pronotum small, but generally fused with the rest of the very compact thorax, in which the mesothorax largely predominates. Wings membranous, slender, the front wings much larger than the hind pair and sometimes folded once longitudinally; both with few and rather distant veins, which often do not reach the outer margin of the wing and beyond the middle are usually connected by cross-veins to form rather large polygonal cells; sometimes nearly all the veins are aborted; no reticulation. Legs very slender. Abdomen frequently furnished with an exserted, needle-like, complex sting or ovipositor. Metamorphosis complete, the appendages of the pupa free. Larva of two types, eruciform and vermiform, corresponding to structural distinctions in the imago. Habits terrestrial, but many of the larvæ inhabit galls or are parasitic in the larvæ of other insects, and the pupæ are generally inclosed in a dense silken cocoon. The order comprises the most highly organized and complex social communities among insects.

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[1] Since this was written Dr. Oppenheim, of Berlin, has published an important paper dealing mostly with Mesozoic Lepidoptera (Die Ahnen unserer Schmetterlinge in der Sekundär- und Tertiärperiode. Berl. entom. Zeitschr. Band XXIX. Pl. 10–12. 1885). Eight species are described and figured. Two of them, from the Brown Jura of Siberia, belong to one type and are considered as nearly related to Cossus and Phragmatœcia. The neuration, as figured separately on the plate, appears, however, to differ in important particulars from the excellent figures of the original fossils given beside them. They are named *Palæocossus jurassicus* and *Phragmatœcites Damesii.* The others all come from the White Jura of Solenhofen and include not only such as had before been referred to Sphinx, but also *Belostomum elongatum*, which, following Assmann, has in this essay been placed under Hymenoptera; they form a very distinct type, which, in all respects but the neuration of the wings, reminds one strongly of the Sphingidæ. This exception is, however, a marked one and forbids their being looked on as Lepidoptera in a strict sense. Dr. Oppenheim has therefore considered them as forming a distinct order, giving them the name of Rhipidorhabdi. They are referred to the genera Rhipidorhabdus and Fabellovena, with three species each. It remains to be seen how close the relationship may prove to be between these Rhipidorhabdi and the Jurassic species from Siberia. It looks as though it were closer than Dr. Oppenheim indicates.

The number of Hymenoptera which have been found in Pretertiary deposits is so small that it will be best to consider them in a single paragraph. Eight or ten species only are known, most of which have been described from Solenhofen and are generally very obscure objects, of which little more can be said than that they are probably Hymenoptera. Such are two species of Apiaria described by Germar and by Weyenbergh, though Assmann considers *Apiaria antiqua* to be a Sirex and *Apiaria lapidea* the same as Germar's *Carabicina decipiens.* Two others are looked upon by Assmann as Uroceridæ, namely, *Belostomum elongatum*[1] and *Sphinx Schroeteri* of Germar. *Bombus conservatus* Weyenb. presents no tangible characters, and it is impossible to say whether his *Anomalon palæon* is a Hymenopteron or not. The other Mesozoic species are in better state of preservation and, excepting the eggs of a Nematus (one of the Tenthredinidæ) figured by Fritsch from the Cretaceous of Bohemia, are all Formicidæ. One of the oldest Hymenoptera known comes from the Lias of Switzerland and was figured by Heer under the name of *Palæomyrmex prodromus;* the other two are from the English Purbecks and were figured by Westwood under the name of *Formicium Brodiei* and *Myrmicium Heeri.*

1. Tribe TEREBRANTIA Latreille.

1. Family Tenthredinidæ.

This family has been found in only one or two localities in Tertiary deposits and is very rare in amber, single specimens of a winged Cephus and Emphytus and of larval Cimbex, Lyda, and Lophyrus having been reported by Menge. Gravenhorst and Schlotheim also state that Tenthredo is found in amber. Curtis reports the latter genus also from Aix, as does Serres, together with species of Pteromus and Cryptus. Besides this, Heer describes two species of Cephites from Oeningen and two of Tenthredo from Oeningen and Aix. On the other hand, considerable numbers have been found at Florissant, some seventy specimens having occurred, of at least twenty species.

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[1] See note on p. 96.

2. Family **Uroceridæ.**

The only Tertiary fossils of this family known are a species of an extinct genus, Urocerites, described by Heer from Radoboj, and an undescribed species from Florissant. (For probable Mesozoic forms, see the preceding page.)

3. Family **Cynipidæ.**

Gravenhorst states that Diplolepis occurs in amber, from which deposit Presl describes a species of Cynips. Menge also states that the family is found in amber, but in scanty numbers. Heyden refers doubtfully to Cynips or Pteromalus some mines in leaves of Juglans from Salzhausen. The family is very abundant at Florissant, and two or three galls have been obtained there.

4. Family **Pteromalidæ.**

This family is much more abundant in amber than the preceding, Menge mentioning forty-eight specimens in his collection. It occurs also at Florissant, and Heer refers under the name Pteromalinites to a species at Oeningen. None whatever have been described.

5. Family **Chalcididæ.**

Of this family Heer describes a species of Chalcites from Aix and Scudder one of Decatoma from Wyoming. Chalcididæ occur at Florissant in some abundance, at least four or five species and twenty specimens having been obtained.

6. Family **Proctotrupidæ.**

This family of minutest insects is known only from amber. Burmeister and Gravenhorst report Ceraphron and Psilus as occurring in the Prussian amber, and Myrmar, that mere speck, is figured by Duisburg from Prussian and by Malfatti from Sicilian amber.

7. Family **Braconidæ.**

Two species of Bracon have been described from Sieblos and Wyoming, and an extinct genus, Calyptites, from British Columbia. Bracon is also said to occur at Aix and in British Columbia, as well as in Prussian and Sicilian amber. Gravenhorst says that Chelonus also occurs in amber and Serres credits a species of Agathis to Aix. Many specimens of this family have been found at Florissant.

8. Family **Ichneumonidæ.**

This family is well represented in Tertiary deposits, though no great number have yet been described. Most of these have been published under the generic names Pimpla and Ichneumon, the former being represented by seven species, from Aix, Radoboj, amber, and British Columbia, and the latter by four, from Aix, Oeningen, Radoboj, and Utah, besides which there are references to others in amber and at Aix. Heer, also, under the generic name Ichneumonites, describes one species each from Oeningen and Radoboj, suggesting that the one from the latter place may be a Trogus. From Radoboj come also single species of Acœnites and Hemiteles, and from Oeningen, of Anomalon and Cryptus, both of which are also reported from Aix and the latter from amber. Ophion is stated to occur at Aix, and that or Campoplex in the Quaternary of Pianico in Italy. At Florissant this family is remarkably well represented, hundreds of specimens occurring, with a remarkable variety of species and genera.

9. Family **Evaniidæ.**

Burmeister recognized Evania among amber insects.

2. Tribe ACULEATA Latreille.

1. Family **Formicidæ.**

That this family was an ancient one and represented to some extent in Mesozoic times may be seen above (p. 97). No other family, not only of Hymenoptera but even of any Hexapoda, was so abundant in Tertiary times, whether in species or in individuals. At Florissant they comprise, in individuals, about one-fourth of all the insects, and more than four thousand specimens have already been brought from that locality. Mayr has carefully studied nearly fifteen hundred specimens from amber, in which he has detected forty-nine species of twenty-three genera. More than one hundred and seventy species have been described from different localities, but by far the largest number from amber and Radoboj, and thirty-four or more genera are recognized. Of these the largest number of species belong to the *Formicidæ* proper; of genera, to the *Myrmicidæ.*

Of the latter subfamily Mayr finds three extinct genera in amber, namely, Stigmomyrmex with two species and Enneamerus and Lampromyrmex with one each. Heer describes four Radoboj species under the new generic name Attopsis, which Mayr finds is the same as the existing but later founded genus Cataulacus. Heer also describes a fragment from Spitzbergen under the generic name Myrmicium. Mayr describes a species of Lonchomyrmex from Radoboj, which Assmann finds also at Schossnitz. Besides these the Prussian amber has furnished the genera Aphænogaster, 2 sp.; Macromischa, 4 sp.; Myrmica, 2; Leptothorax, 1 sp.; Monomorium, 1; Pheidologeton, 1, and Sima, 3 sp. Of these Aphænogaster possesses four other species from Oeningen, Radoboj, and British Columbia; Myrmica, no less than twelve other described species from Oeningen, Radoboj, Parschlug, and Krottensee, and is recorded from the Isle of Wight; Leptothorax has another species at Radoboj; and Pheidologeton has two others, from Schossnitz and Krottensee. A species of Crematogaster also occurs at Radoboj, with one of Pheidole and one referred doubtfully to Solenopsis, while Guérin figures two species of ants in Sicilian amber, which Erichson refers to Pseudomyrme.

Of the *Poneridæ* we have twenty-seven species, belonging to seven genera, of which the greater part are accounted extinct, viz: Bradoponera and Prionomyrmex from amber, with one species each; Imhoffia, with two species from Oeningen; and Poneropsis, with a dozen species from Radoboj and Oeningen. Besides these, amber has furnished, according to Mayr, Ponera with two species and Ectatomma with one, while F. Smith refers one he has seen to Anomma. Ponera is also represented in the rocks, having seven species in the deposits of Radoboj, Oeningen, and Parschlug.

Over one hundred species of *Formicidæ* proper are described, but only two of the genera are accounted extinct, Gesomyrmex and Rhopalomyrmex, each with one species from Prussian amber. This deposit has also furnished Camponotus, 3 sp.; Œcophylla, 1 sp.; Prenolepis, 2 sp.; Plagiolepis, 5 sp.; Lasius 4, sp.; Formica, 13 sp. (only 1, however, recognized by Mayr); and Hypoclinea, 8 sp.; besides, according to F. Smith, a Polyrhachis; while Malfatti figures a Tapinoma from Sicilian amber. Of these genera, Camponotus has six other species or varieties, found at Radoboj, Oeningen, and in Utah, and has, besides, been recognized in the Isle of Wight Eocene; Œcophylla has another species, occurring both at Radoboj and Kutschlin; Lasius, eleven species, at Radoboj, Schossnitz, and Wyoming; Hypoclinea, five others, from Radoboj, Kutschlin, and British Columbia; while Formica possesses no less than thirty-four species from various parts of the continent of Europe, but mostly from Radoboj and Oeningen, and one from British Columbia. Besides this, the genus has been recognized in Sicilian amber and at the Isle of Wight. Finally, four species of Liometopum are known from Radoboj and Utah.

2. Family **Chrysididæ.**

Giebel describes a species of Chrysis from amber, and at least one species, with the metallic-green reflections of the abdomen still remaining, occurs at Florissant. A species of Cleptes is mentioned by Beck as occurring in the Pleistocene deposits of Jutland.

3. Family **Mutillidæ.**

Menge found half a dozen specimens of this group in amber, previously reported to occur therein by Brongniart.

4. Family **Scoliadæ.**

Heer describes a Scolia from Oeningen and the family occurs at Florissant.

5. Family Pompilidæ.

Oeningen furnishes a species of Pompilus; Pepsis occurs, according to Burmeister, in amber; and the group is represented among the Florissant species.

6. Family Sphegidæ.

Heer describes a Sphex from Radoboj and two species of Ammophila from Oeningen. The latter genus is found at Florissant with other genera. In amber Menge found the family abundant, reporting sixty-nine species of *Crabronidæ* and twenty-two of other Sphegidæ, but no genera are mentioned by him.

7. Family Vespidæ.

Three species of Vespa are known from Radoboj, Parschlug, Moudon, and amber, and the genus is also reported from Aix. Polistes, of which one species is named from Oeningen, is also reported by Serres at Aix, by Latreille at Chaumerac, and by Scudder at Florissant, at which last place several other genera and a considerable number of species occur. Only three specimens of this family are reported in amber by Menge.

8. Family Apidæ.

This family was tolerably abundant in Tertiary times, to judge by the comparatively large number of fossil species known. Of the *Andrænidæ* mention is made only of their occurrence, rarely, in amber by Menge, who found two specimens of a genus allied to Dasypoda, and at Florissant, but the *Apidæ* proper are more numerous. From Oeningen and Radoboj, Heer describes five species of Anthophorites, and another comes from Corent, besides a species of Anthophora from Rott and one indicated from amber; seven species of Bombus, from Oeningen, amber, Radoboj, Rott, and Krottensee, besides one amber species referred by Motschulsky to Bombusoides; two each of Apis and Osmia, from Oeningen and Rott, besides an Apis from amber and an Osmia from Orsberg; finally a Xylocopa described from Oeningen and a Trigona said by Burmeister to occur in amber. A number of species of this family, mostly represented by single individuals and generally not very well preserved, occur at Florissant.

HISTORY AND DISTRIBUTION OF FOSSIL INSECTS.

Marcel de Serres's Géognosie des terrains tertiaires may be looked upon as the first general work on fossil insects. His fourth book, which treats wholly of insects, closes with a tableau général wherein one hundred and two genera of insects are enumerated, with two hundred and nineteen species. This work included the first general notice of the insects of Aix (nearly eighty genera being mentioned), which, had it not been published separately in advance, would have appeared, curiously enough, at the same time as Curtis's independent account of the insects of the same deposit (in which forty-seven species are enumerated). That year, 1829, may therefore well count as the starting point of our definite knowledge of fossil insects. In the following year appeared Berendt's first notice of the amber insects of his collection; but these were not carefully worked out, and then but partially, until twenty-five years later, previous to which epoch a marked increase in our knowledge and a widening of our horizon had been brought about by the publications of Germar and Goldenberg on the insects of the Coal Measures; of Brodie, Westwood, and Germar on those of the secondary rocks; and especially those of Heer (not to mention Heyden, Charpentier, and Unger) on the insects of Tertiary deposits. Since then contributions have been continually made, extending the field and introducing new elements of discussion, prominent among which may be mentioned the discoveries of Eugereon, Protophasma, and Palæoblattina in Europe and a vast store of Carboniferous and Tertiary insects in America.

About 1856 the number of fossil species was estimated by Bronn as a little more than 1,800 (7 Paleozoic, 126 Mesozoic, 1,682 Tertiary) and by Giebel as nearly 2,000 (21 Paleozoic, 231 Mesozioc, 1,744 Tertiary). At present it is probable that 2,600 species have been actually described or at least fully named (of which 155 are credited to the Paleozoic, 475 to the Mesozoic, and 1,972 to the Tertiary), a number which would be very largely increased, especially in the Tertiary insects, were we to include in our enumeration, as was done by Bronn and Giebel, those which had received generic indications only. The immediate future is likely to bring the largest contributions to our knowledge from the Coal Measures of Commentry in France and the Tertiary tufa deposits of Florissant in America; although, since our knowledge of fossil insects is almost exclusively derived from Europe and North America, we cannot yet tell what to expect from other parts of the world.

The oldest known insect is *Palæoblattina Douvillei*, recently described by Brongniart from the Middle Silurian of France and of undetermined affinities. It is older even than the earliest known arachnids (Upper Silurian) or myriapods (Lower Devonian) and is followed at a considerable distance by the oldest insects of America (Upper Devonian). It is, however, only when we reach the productive Coal Measures that we arrive at insect faunas of considerable extent, such as those especially of Commentry in France and of Mazon Creek in Illinois. Other considerable deposits are found in the coal-fields of the Saarbrück and Wettin basins of Germany, the Belgian and British coal-fields, and in America the coal-basins of Nova Scotia and Pennsylvania. The Permian offers comparatively few species, but some of these are of particular interest (e. g., Eugereon), and the Trias is almost wanting in fossil insects, except in the South Park of Colorado, where about twenty species have recently been obtained, affording transitional forms among the cockroaches. Later Mesozoic deposits have yielded nothing in America, but much in England, where nearly all the strata from the Lower Lias to the Wealden have been productive. On the continent of Europe prolific Liassic deposits have been discovered at Dobbertin in Germany and Schambelen in Switzerland, while the oölitic beds of Solenhofen in Bavaria are world-renowned. Scanty returns have come from the Cretaceous, but the early Tertiaries have yielded an abundant harvest in the amber deposits of the Baltic shore, the marls of Aix, and in America at Florissant and Green River, while the Middle Tertiaries of Oeningen, Radoboj, Parschlug, Auvergne, and the Rhenish brown coal have been scarcely less prolific.

The relation between the Carboniferous insect faunas of Europe and North America (those of other continents are absolutely unknown) is by no means so close as in the case either of the arachnids or of the myriapods. While, for instance, the bulk of the fauna was in each hemisphere made up of cockroaches, one entire division of these (Mylacridæ), with five genera, was restricted to America and of the eight genera of the other division (Blattinariæ) only one-half (comprising, however, the most prolific genera) were common to both hemispheres; no identical species occur. In the other Paleozoic groups the difference is even more striking, the genera being rarely common to the two countries and whole series of forms being developed in one region which are completely wanting in the other, where they are replaced by an entirely different set. How far this statement of facts, based on present knowledge, may be modified when the insects of Commentry come to be known, it is, of course, impossible now to say, but Mr. Brongniart[1] informs me that very few American types have been found there. Nevertheless one is struck by the common occurrence in the two hemispheres of such striking forms as Titanophasma and Megathentomum, and nearly all the families occur on both continents.

Our knowledge of Paleozoic insects dates back only a half century to the time (1833) when the wing of *Lithosialis Brongniarti*, from Coalbrockdale in England, was submitted to Audouin and reported upon by him to the French Academy of Sciences and elsewhere. He considered it a neuropterous insect allied especially to Corydalis and Mantispa. This and others closely allied to it have been variously interpreted by subsequent writers as neuropterous or orthopterous, and indeed, up to the commencement of Goldenberg's discoveries in the Saarbrück basin, hardly a score of Paleozoic insects being known, there were not sufficient grounds whereon to base an opinion concerning these ancient wings. His explorations and those following in their train have within the last ten years completely changed the aspect of the Paleozoic field and enabled us to obtain a more accurate picture of early insect life. This is mainly due, besides the mere abundance of material, to the discovery of two insects, Eugereon and Protophasma. The former, studied by Dohrn, possessed four similar, large, membranous, reticulated wings, like those heretofore classed as neuropterous, with prolonged mouthparts, forming a rostrum similar to that now found in Hemiptera. The latter, studied by Brongniart, possessed wings which had up to that time been unhesitatingly described as neuropterous, attached to a body which was plainly that of a phasmid, one of the most peculiar tribes of Orthoptera. These generalized types have given a clew to the study of Paleozoic insects and have first rendered possible the discovery that there existed among these ancient forms no ordinal distinctions, such as obtain to-day, but that they formed a single homogeneous group of generalized hexapods, which should be separated from later types more by the lack of those special characteristics which are the property of existing orders than by any definite peculiarities of its own. Yet among the Paleozoic forms which by special characteristics can be claimed as the immediate progenitors of some existing families of insects, we find upon sufficient examination some fundamental structural features separating them as a whole from those of later times, separating them indeed more widely from them than from their nearest contemporaries. In one group, the cockroaches, where superficial observers claimed a very close agreement between ancient and modern types, it has been shown that their front wings alone differ in at least three important particulars from those of later times, and the passage between the ancient and modern types has been traced in the Triassic cockroaches of Colorado.

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[1] Mr. Brongniart has kindly sent me in manuscript an outline of his classification of Paleozoic insects, largely based on those found at Commentry, read at the Sorbonne in April, 1885; but as it consists of names only, and most of these are new, it is impossible to make use of it on this occasion excepting in the most general way. He recognizes five orders, fifteen families, and fifty-four genera, exclusive of the cockroaches. Thirty-eight of these genera and at least fifty-nine species are found at Commentry.

Every one of the existing orders of insects, however, is found in the middle of the Mesozoic period, and most of them in the early Mesozoic, full-fledged one might say, with a considerable development into existing families; and it is therefore presumable that, were the insects in general of Triassic times only as well known as are the cockroaches, we should be able to trace the differentiation of the ancient Palæodictyoptera into the existing orders of insects.

At present this is not possible, excepting by rather large presumption and on certain lines. Thus we can see that the modern cockroaches descended from the ancient, and it is highly probable that the Mantides were an offshoot from the same branch, possessing the same characteristic impression of the principal anal vein of the front wing. The ancient walking-sticks were evidently the precursors of the present Phasmida, although the wings and especially the front pair have little in common. It would seem not improbable that the saltatorial Orthoptera also originated from the Protophasmida. There can hardly be a doubt that the Palephemeridæ were the precursors of the existing May-flies, the Hemeristina were probably followed by the Sialina, and Fulgorina and Phthanocoris seem to have foreshadowed the Homoptera and Heteroptera respectively; but to what Eugereon led or the four families of neuropteroid Palæodictyoptera, called by me Homothetidæ, Palæopterina, Xenoneuridæ, and Gerarina, it is far more difficult to say. They appear to have about equal relations to the Perlina and Termitina among the Pseudoneuroptera and to the Sialina, Hemerobina, Panorpidæ, and Phryganidæ among the Neuroptera proper, while at the same time they are more nearly related to each other than are Fulgorina and Phthanocoris, indicating thus a greater antiquity for the separation on the one hand of the Homoptera and Heteroptera, and on the other of the Neuroptera as a whole and the Orthoptera, than for that of the Neuroptera vera and the Pseudoneuroptera, and rendering the separation of the last two as distinct orders unjustifiable on paleontological grounds, at least as long as all the Hemiptera are classed in one ordinal group. By thus tracing the probable genetic relation of Paleozoic to later types, we are able to distinguish among the former the outlines, or premonitions, as it were, of certain structural features, which afterward became fixed as peculiarities of one or another order, and in this way select from the more ancient forms such as may be distinguished as orthopteroid, neuropteroid, &c.

We have thus accounted for nearly all the principal existing groups of the lower hexapods, or Heterometabola, and we note, in passing, that as a general rule one common change has taken place in their wing structure in the passage from Paleozoic to later times. In all known

Paleozoic insects, excepting only Phthanocoris, the front wings are equally membranous and diaphanous with the hind wings and of much the same general size, while in most of their later descendants in the groups specified the front wings are generally smaller than the hind wings and have a more or less definitely coriaceous structure or have the veins much thicker and more approximated than in the hind wings.

In this survey, however, we have made no mention of the Coleoptera or of the Metabola. As to the latter, we note that the front wings are invariably diaphanous like the hind wings (when these exist), and that the veins of the front pair are neither abundant nor noticeably stout. In short they retain the characteristics of the front wings of Paleozoic insects more than do any of the Heterometabola, unless we except, in certain points, the Neuroptera, many of which are equally or even better comparable. It seems therefore highly probable that the Metabola and the Neuroptera sprang together from the allied families of Palæodictyoptera whose obscure common relation to the Pseudoneuroptera and Neuroptera proper has been referred to above.

When we come to the Coleoptera the case is different. None have been found in Paleozoic rocks,[1] though they occur with fully developed characteristic elytra in the very earliest Mesozoic deposits, as the Rhaetic and even the Trias. Nor do we find anything in the least degree allied to the elytral structure among any of the Paleozoic insect types. But we do find traces of borings in wood similar to those made by Coleoptera to-day, and it is not unreasonable to suppose that all the Paleozoic ancestors of Coleoptera were wood-borers throughout life (a habit to which the ample Carboniferous forests would certainly have afforded full play), and that their absence from the rocks is due to this secretive habit. Certainly the gradual assumption of elytra for membranous front wings would be particularly favorable to a creature living in hard-walled burrows, where membranous wings would suffer abrasion; and, although this is an almost purely hypothetical assumption, we have a certain warrant for it in the probability that Coleoptera, like the other orders, had purely Palæodictyopteran ancestors in Paleozoic deposits and in three facts: (1) the absence of coleopterous remains in Paleozoic rocks, (2) their presence in Triassic and Rhaetic deposits, and (3) the occurrence in Carboniferous trees of borings similar to those now made by beetles in like places.

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[1] Long after this manuscript was sent to Germany I learned, through letters from E. Dathe to Hauchecorne (Zeitschr. der deutschen geol. Gesellsch., 1885, 542) and to Dr. Zittel, that the Silesian culm of Steinkunzendorf had furnished five beetle remains, of which four are elytra and one a specimen showing elytra and pronotum. The largest elytron is said to be 18 millimeters long and 14 millimeters broad, the smallest 8 millimeters long and 6 millimeters broad (the breadth probably including a pair of elytra). One specimen examined by Dr. F. Karsch, of Berlin, was taken by him to be the elytron of a carabid or of a tenebrionid. Further details of this find will be awaited with interest.

We may then draw the following picture of the probable sequence of events in the geological history of insects and of the peculiarities of the different epochs—a picture which does not carry us back to any apterous condition of hexapods, the only speculations on this subject drawn from existing biological data (however probable they may be or however unanimously such views may be held by those who have speculated on the subject) being altogether unsupported by a scintilla of paleontological evidence.

The earliest insects, then, were generalized hexapods, Palæodictyoptera, in which the four wings were equally and similarly developed, membranous, and with very simple neuration. Their metamorphoses were simple and "incomplete," the young leaving the egg with the form of the parent but without wings, the assumption of which required no quiescent stage before maturity. They appeared probably as early as any land-plants, certainly by the middle of the Silurian epoch, and continued as a homogeneous type until the end of the Paleozoic period. Certain indications of differentiation were present, but they were largely those which characterize in later times simple families or limited groups of families, such as an excessively long and slender body (Protophasmida) or an anal area separated from the rest of the wing (the front wing only) by a deep furrow (Palæoblattariæ), but in some cases foreshadowing ordinal distinctions, as in the thickening of the basal portion of the front wing (Phthanocoris). Probably also a life-long burrowing habit of some wood-feeding forms had induced in them an incipient hardening of the front wing in preparation for a greater change that awaited them. Most of these Paleozoic forms were of large size, with bulky bodies and ample wings. In repose they rested their wings by overlapping on their abdomen, a habit which very few of their descendants have altogether overcome (butterflies, most dragon flies).

With the advent of Mesozoic times came the greatest changes which the insect world has seen. Nearly all along the line there was developed a differentiation of the front and hind wings, the latter growing relatively larger, with a special expansion of the anal area, the former changing its membranous, diaphanous character for one more or less pergamentous or corneous, or approximating this condition by a multiplication or an increase in the size of the nervures, while special structural features were assumed by each particular type, as for instance in the cockroaches, where by the amalgamation or altered direction of certain veins of the front wings they became still further changed in character from the hind pair. Thus in the same Triassic deposits we find side by side several species of cockroaches which, examined together, bridge over the distinctions between the ancient Palæoblattariæ and the modern Blattariæ: First, those in which the front wings are diaphanous, with distinct mediastinal and scapular veins, and the anal nervures impinge on the border of the wing; next, those having a little opacity of the front wings, with blended mediastinal and scapular, and the anal veins as before; then those with still greater opacity, with the same features; and finally those having the structure of the front wings coriaceous or leathery, with blended mediastinal and scapular veins and anal nervures impinging on the anal furrow. By such steps as these were the undifferentiated Palæodictyoptera transformed into the modern types of Orthoptera, Neuroptera, Hemiptera, and Coleoptera. It is probable that these orders were first differentiated, and later the Metabola, for in the Trias and Rhaetic we find only the Heterometabola, and not yet all of them. Still, looked at in a broad way, we may say that all the existing orders of insects originated early in Mesozoic times, for the Diptera and Hymenoptera appear in scanty numbers in the Lias and the Lepidoptera in the Oölite. The Metabola, however, are nowhere abundant in the Mesozoic period and are always subordinate to the Heterometabóla, though as soon as the Tertiary period opens they assume a preponderating part, which was probably even greater than appears, since the readier preservation of Coleoptera in rock deposits undoubtedly gives them a better relative standing in our knowledge of the past than is really their due. We may then state in broad terms that, as far as insects were concerned, the Paleozoic epoch was the age of Palæodictyoptera and especially of cockroaches (since nearly half the known species belong to that group), that the Mesozoic epoch was the age of Heterometabola, the Cenozoic of Metabola and Coleoptera, while the present is the age of Coleoptera and Metabola, the relative proportion of Coleoptera to the other orders having steadily increased from the close of the Paleozoic epoch.

The "complete" metamorphosis of the higher (and of a few lower) insects is now generally looked upon as a secondary adaptive feature, originating from an "incomplete" metamorphosis, the very existence of which among so many, and these exclusively the lower insects, is an argument in favor of such a view. That these more complex metamorphoses originated simultaneously with the segregation of the existing orders of insects is rendered probable from the similarity of larval form and structure in different orders, as the maggot-like larvæ of Musca, Vespa, and Curculio, for instance, as well as from the existence of very different types of larvæ within the same order, as, for example, Stratiomys and Œstrus, Tenthredo and Bombus, Dytiscus and Calandra. The striking hypermetamorphosis of some Meloidæ, not shared by neighboring families of Coleoptera, gives plain proof of the amount of change which may be acquired within narrow limits and in comparatively brief time. There is no good evidence that the Meloidæ were differentiated before the Tertiaries, yet Menge has found in the amber deposits of the Oligocene what are apparently the larvæ of Meloidæ in the triungulin stage. It may be stated in general terms that, although comparatively little is known of the earlier stages of extinct insects, all our knowledge tends to show that the present general conditions of metamorphosis existed at least as far back as the middle or latter part of the Mesozoic period. The larvæ of the Oligocene (of which we know most) had all the characteristics of those of the present day, and of the few from the Mesozoic rocks the the same may be said, with the possible exception of the oldest known larva, ***Mormolucoides articulatus***, from the Trias of New England, which is of a somewhat anomalous character, though probably a sialid. From the Paleozoic rocks no larvæ whatever are known, whether of the "complete" or "incomplete" type.

The sexes, as is well known, are now completely distinct in insects. Certain peculiarities of secondary sexual dimorphism accompanying special forms of communistic life, such as the "neuters" and "workers" in Hymenoptera and the "soldiers" among the Termitina, are also found, as would be expected, among the fossils, at least through the whole series of the Tertiaries. The same may be said of other sexual characteristics, such as the stridulating organs of the Orthoptera, and of peculiarities of oviposition, as seen in the huge egg capsules of an extinct sialid of the early Tertiaries. The viviparity of the ancient Aphides is suggested, according to Buckton, by the appearance of one of the specimens from the Oligocene of Florissant, while some of the more extraordinary forms of parasitism are indicated at a time equally remote by the occurrence in amber of the triungulin larva of Meloe, already alluded to, and of a characteristic strepsipterous insect; not only too are the present tribes of gall-making insects abundant in the Tertiaries, but their galls as well have been found.

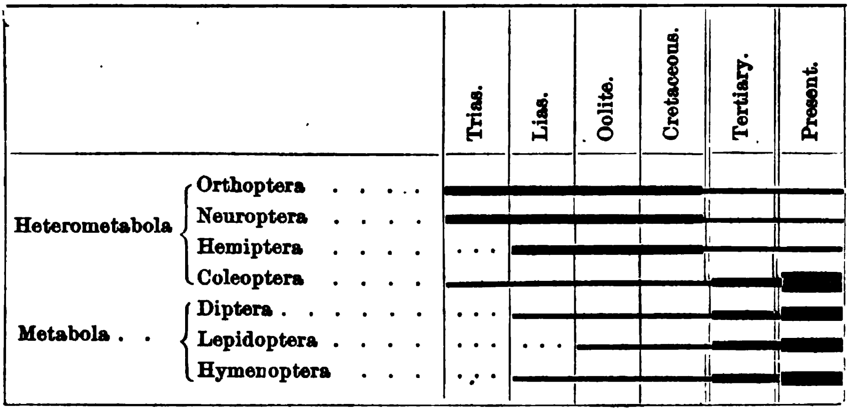
In fact, by the presence in the rocks of nearly every group in which interesting special biological phenomena have been found in present times, we are forced to believe it highly probable that the general features of insect life, with all their varied dependence upon their environment, have remained almost without change through at least the Tertiary epoch. In keeping with this is the fact, not too much to be relied upon, that the larger proportion of Tertiary insects, and no small number of Mesozoic types as well, have been referred to existing genera. This may be due in part to their incomplete preservation or to their insufficient study, and it is highly probable that one or the other of these causes may account for most of the cases which are known from the Mesozoic deposits. But these explanations will not fully suffice for the Tertiary deposits, since we can test the matter to a certain extent in the excellent relics of the amber, at least in the groups which have been carefully studied. Here we find that, as a general rule, only from a fourth to a third of the genera are extinct, and these genera are usually those which are least prolific. Of the twenty-three genera of Formicidæ, carefully studied by Mayr, only six (with seven species out of forty-nine) are looked upon as extinct; and of the Psocina, studied by Hagen and Kolbe, three out of the ten genera (five species out of fifteen) are in the same category.

The following table shows in a condensed form the geological distribution of the orders and larger divisions of fossil insects. The weight of the lines indicates in a very general way the comparative development and importance of the type.

Geological distribution of insects.

	Silurian.	Devonian.	Carboniferous.	Permian.	Trias.	Lias.	Oölite.	Cretaceous.	Tertiary.	Present.
Palæodictyoptera	—	—	━	━	—					
Orthoptera	...	...	...	...	━	━	━	━	—	—
Neuroptera:										
Pseudoneuroptera	...	...	...	...	...	━	━	━	—	—
Neuroptera vera	...	...	...	...	━	━	━	━	—	—
Hemiptera:										
Homoptera	...	...	...	...	...	━	━	━	—	—
Heteroptera	...	...	...	...	...	━	━	━	—	—
Coleoptera:										
Rhynchophora	...	...	...	...	—	—	—	—	━	█
Heteromera	...	...	...	...	...	—	—	—	━	█
Phytophaga	...	...	...	...	—	—	—	—	━	█
Lamellicornia	...	...	...	...	...	—	—	—	━	█
Serricornia	...	...	...	...	—	—	—	—	━	█
Clavicornia	...	...	...	...	...	—	—	—	━	█
Adephaga	...	...	...	...	...	—	—	—	━	█
Diptera:										
Eproboscidea	...	...	...	...	...	...	...	...	...	—
Cyclorhapha	...	...	...	...	...	...	—	—	━	█
Brachycera	...	...	...	...	...	—	—	—	━	█
Nematocera	...	...	...	...	...	—	—	—	━	█
Lepidoptera	...	...	...	...	...	...	—	—	━	█
Hymenoptera:										
Terebrantia	...	...	...	...	...	...	...	...	━	█
Aculeata	...	...	...	...	...	—	—	—	━	█

Or, if we present the same facts for the existing orders simply, the sequences insisted upon above will be more clearly seen, as in the following table:



COMPARATIVE HISTORIES OF MYRIAPODA, ARACHNIDA, AND HEXAPODA.

In conclusion we may note the contrasts which the geological histories of the Myriapoda, Arachnida, and Hexapoda present when compared.

In the Arachnida four orders existed side by side in Paleozoic times, the most abundant of them disappearing at its close; the other three have continued to the present time and appear to have been as widely separated from each other at that distant period as now, and only one of them has since received a preponderating development. In addition to this, three new orders make their appearance in Tertiary times, but, two of them being the very lowest of their class, their apparent absence from Mesozoic deposits is probably due to the "imperfection of the geological record," and it is not improbable that all of these may prove to be the differentiated descendants of Anthracomarti, the order peculiar to the Paleozoic era.

In the Myriapoda we find two very diverse orders existing in Paleozoic times, which disappeared with that epoch and were replaced in later times by two others equally and to some extent similarly distinct from each other and from those which preceded them. It is probable that they are the descendants of the early types and that a fifth order, at present only known in recent times, was also derived from one of them.

In the Hexapoda, all known Paleozoic forms are referable to a single order, which disappeared at or shortly after the close of that era, being replaced in the Mesozoic epoch, through differentiation, by the seven existing orders.

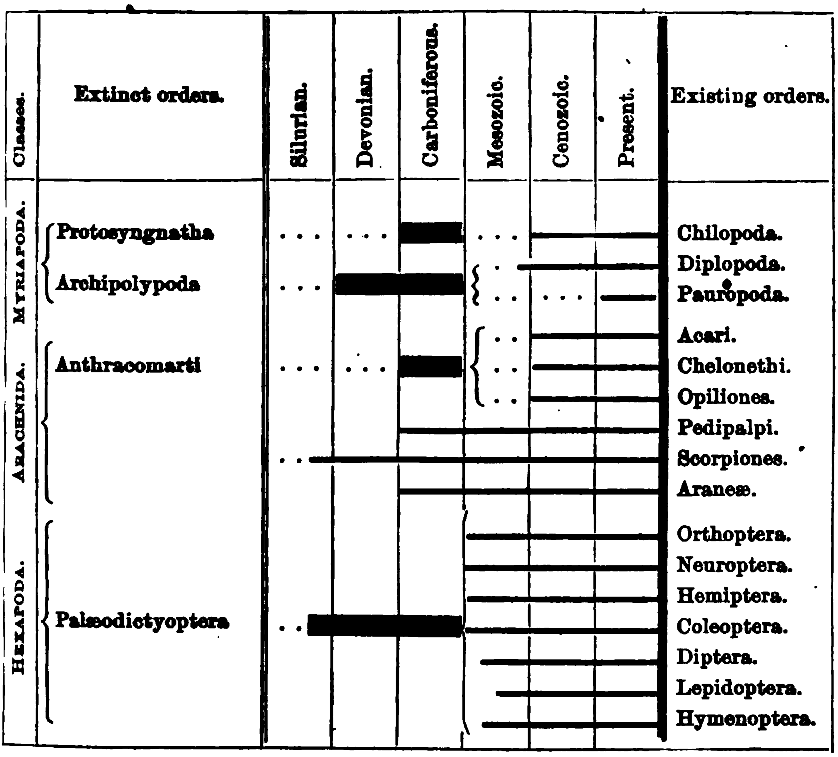
We thus find that in the Paleozoic epoch we have in the Arachnida one extinct and three existing orders; in the Myriapoda two extinct orders and none of the existing; in the Hexapoda one extinct order and no existing ones, all of these being afterwards differentiated from the common Paleozoic stock.

In passing backward, then, we reach a common ancestral stock for the Hexapoda as soon as the close of the Paleozoic epoch, and we continue to retain the same as far back as the Middle Silurian. In the Myriapoda we lose all trace of the existing orders when we reach Paleozoic times, but find them replaced by others as widely differentiated from each other as existing types among themselves, and one of these types we trace back to the Middle Devonian. In the Arachnida one half of the existing orders may probably be traced to a Paleozoic type since extinct, while the other half occur side by side with this extinct type and one of them is found as far back as the Upper Silurian.

Notwithstanding, then, that winged insects are at present known from older rocks than any containing either Arachnids or Myriapods, it would seem highly probable that the ancestral stock of these last will yet be found in older deposits than will the true insects. The relationship of the Arachnida to the Merostomata and the probability that some of the early Myriapoda were amphibious render it further probable that the ancestral stocks of Arachnida and Myriapoda were of aquatic habit, while it is evident that the ancestral winged Hexapoda must have been, at least in adult life, terrestrial. Their apparition would not therefore be expected to antedate that of land plants.

The following table, in which the heavy lines are meant to indicate the chronological range of the presumed ancestral and extinct stocks, while the lighter lines show that of the existing orders, will illustrate these statements graphically. The purely hypothetical portions are given in dotted lines.

Chronological range of presumed ancestral and extinct stocks.



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NOTICE.

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This bulletin will be included in Volume V.

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77a

LISTS AND ANALYSES

OF THE

MINERAL SPRINGS

OF THE

UNITED STATES

[A PRELIMINARY STUDY]

BY

ALBERT C. PEALE, M. D.

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MINERAL SPRINGS OF THE UNITED STATES.

By A. C. Peale, M. D.

INTRODUCTION.

In attempting the collection of data for the statement of the commercial value of the mineral waters of the country for publication in the report on the Mineral Resources of the United States, 1883 and 1884,[1] it was necessary as a prerequisite to have a list of the springs from which these waters are derived. An examination of the few general works on the subject very soon showed that all existing lists were incomplete. The tables given in this paper were therefore compiled, as the first step in the preparation of the mineral spring statistics of the United States. They were omitted from the paper published in Mr. Williams's report, for want of space. Since the appearance of that report they have been revised and, with the addition of such analyses as could be obtained, prepared for publication as a bulletin of the Survey.

The most complete compilation previously made of the mineral springs of the United States is believed to be that brought together by a committee of the American Medical Association[2] and published in Vol. XXXI of the transactions of the association (1880). It enumerates about 500 localities. Walton's Mineral Springs of the United States and Canada, published in 1883 (third edition), mentions some 279 localities for the United States. Moorman's Mineral Springs of North America, issued in 1873, refers to or describes 171 springs. Bell's Baths and Mineral Waters, which bears the date of 1831, mentions 21 places, which are increased to 181 in his Mineral Springs of the United States and Canada, published in 1855. A. N. Bell's Climatology and Mineral Waters of the United States, published during the latter part of 1885, enumerates 173 localities. The lists prepared for the present compilation include 2,822 localities. Over 600 are places of resort and more than 200 sell the waters to a greater or less extent. The lists may not be complete as to the number of localities and certainly are not so far as the total number of individual springs is concerned, reports not having been received from all the localities. Still, they are published as preliminary to more detailed work, which it is hoped may follow in the future. The information has been derived primarily from the various State geological reports, State guide and hand books, Government geological reports and maps, and various scientific publications. To enumerate all these sources would be giving a large part of the bibliography of the subject, a work now in preparation. Much additional material has been obtained from members of the Geological Survey whose duties have taken them into so many portions of the country. Supplementary data have been received in answer to a special set of inquiries sent throughout the entire country, and efforts have been made to verify the matter presented in regard to the various localities by direct correspondence in each instance.

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[1] United States Geological Survey. Mineral Resources of the United States. Calendar years 1883 and 1884. Albert Williams, jr. Washington, 1885.

[2] Drs. William Pepper, H. I. Bowditch, A. N. Bell, S. E. Chaillé, and Charles Denison. The list is referred to in this paper as "Pepper's list."

The answers to the questions, as a rule, have been very satisfactory. To mention all those to whom the writer is indebted on this score would be impracticable here.

Although the scope of this paper is far from that of a treatise upon the subject of mineral waters, it may perhaps be advisable to repeat here the definition of the term "mineral water." The definition will depend somewhat upon the point of view, whether it be that of the chemist or of the physician or of some one interested only in the commercial aspect of the subject. Water is itself a mineral and is rarely, if ever, found pure in its natural state. As Daubeny says,[1] the term "mineral water" in its most extended sense comprises every modification existing in nature of that universally diffused fluid, whether considered with reference to its sensible properties or to its action upon life. Usually, however, the term is restricted to such waters as contain an unusual amount of mineral matter or which are characterized by an unusual degree of heat. From a therapeutic point of view, all waters that have an effect upon the animal body are mineral waters, no matter how feebly mineralized they may be.

Where the springs have been improved or where the waters have been placed upon the market, the definition has been used in this paper in its widest sense, and therefore all such springs have been included in the tables. The mention of unimproved springs, however, has been restricted so far as possible to those of which the waters are mineralized to a more or less marked degree. A number of the springs included in the tables, although of considerable commercial importance, would perhaps be classed as indifferent when viewed in the light of their chemical composition. It must be remembered in this connection that chemical analyses will not always explain the effects of a mineral water.

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[1] Report on the present state of our knowledge with respect to mineral and thermal waters, by Charles Daubeny, M. D., &c., in Sixth Report of the British Association for the Advancement of Science, p. 1, 1836.

Many springs which have acquired great reputations for their medicinal effects are found, upon chemical examination, to be not so highly mineralized as many potable waters. That their medicinal value is recognized and that they are sources of profit to their owners, and also indirectly an addition to the wealth of the localities in which they are located, seem sufficient reasons why such springs should be noted. It is not proposed to discuss the relative merits of the various springs.

The tables of analyses appended to the lists under the different States will give an idea as to the chemical composition of the various waters. At present the facts as to the therapeutic action of our mineral waters are so meager and our knowledge of their effects is so inexact that it would be useless to attempt their classification from a therapeutic standpoint.

Neither are the data sufficient for a *complete* reference of American springs to a chemical scheme of classification. Of the more than eight thousand springs in our lists only a few more than eight hundred have been analyzed, so that the definite chemical composition of at least nine-tenths of the springs is still unknown.

The classification of mineral waters is a subject the consideration of which would require a separate paper, as its discussion is beset with many difficulties. All that is necessary here is to indicate the principal divisions, to one or another of which the springs in the lists have been assigned in a general way. First, the waters are characterized in regard to their temperatures, as either thermal or non-thermal, the temperature column in the tables indicating, in most cases, to which of these classes the springs belong. Secondly, certain gases are usually present in the water of most springs, and these springs are indicated by the terms carbonated, sulphureted, carbureted, &c. They are also mentioned as chalybeate, alkaline, saline, calcic, silicious, or acid, according to their predominant or characteristic solid constituents, or by a combination of the terms when more than one is present in large quantity.

Brine springs and wells (with a few exceptions where they have been used for medicinal purposes) have been omitted from the tables, as they are generally utilized in the production and manufacture of salt, and are therefore not usually applied to the ordinary uses of mineral springs. They also formed the subject of separate discussion in the Mineral Resources, 1883–'84, for which this paper was originally prepared.

Tables of analyses of the springs for each State and Territory, so far as they have been analyzed, have been compiled, and an attempt has been made to get the analyses in the most authentic form. The results were found stated in some thirty or more ways.

The limited time in which this paper was prepared did not permit the reduction of the analyses to one standard, and they are incorporated in the tables mainly as given in the sources from which they were taken, with the exception that where expressed in grains to fractions of the gallon they were increased to grains per gallon. When not otherwise stated in the tables, the gallon mentioned is the standard United States or wine gallon of 231 cubic inches. Whenever there has been a choice between two or more forms preference has been given to the one expressed as grains per gallon. Although this is not the most scientific method, the majority of the analyses are so expressed. Of 819 analyses 496 are stated in that form. It is popularly supposed to be the most intelligible to the greatest number of persons. But it may be questioned whether grains per gallon is an expression so readily understood as parts to the hundred thousand or parts in one million, &c. Comparatively few persons have very definite ideas as to how much a grain of any particular substance is. When the results of analyses are expressed as grains or parts in 100, 1,000, 6,000, &c., it is only a matter of simple multiplication to bring them into comparable forms.

The figures in the tables, with few exceptions, have been carried out to but two decimal places. Only quantitative analyses are included, and where several analyses of a water have been made all are given, with the dates, as far as they could be ascertained.

It is impossible to mention here all those to whom thanks are due for data used in the preparation of the chemical tables. In connection with each analysis is given the name of the analyst. A great many of the analyses have been taken from State geological reports, and particularly from reports of Government explorations in the case of the Western States. Various correspondents and spring-owners throughout the whole country have contributed information under this head. Others to whom the writer is especially indebted are mentioned under the different State headings in the following pages.

The grouping of the mineral springs of the United States geographically has been by States, according to the scheme of subdivision proposed by Mr. Henry Gannett, geographer of the Tenth Census.[1] This brings the springs of each region into the same section and seems preferable in the present case to an alphabetic arrangement.

The preliminary character of this paper must be kept in view, and it will be esteemed a favor if attention is called to any errors or cases of duplication that may have crept into these pages.

NORTHERN ATLANTIC STATES.

The Northern Atlantic States might, perhaps, be divided, so far as their geological features are concerned, into two divisions, viz, the New England States and those formerly included with the Middle States.

In the former the rocks are of the older formations, referable mainly to the Archean, sedimentary rocks occupying relatively small areas. To this is, perhaps, due the fact that the springs are, as a rule, somewhat less mineralized than are those of the remaining States. Alkaline waters are more frequent in the New England States than in the Middle

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[1] Census Bulletin No. 277, November 1, 1881.

States; but, in both, sulphureted and chalybeate springs predominate, forming more than one-half the whole number.

The Northern Atlantic States naturally have the greatest number of waters that are used commercially. This section has the greatest population in proportion to its area, has long been settled, and is wealthiest. All these are reasons why we might expect to find mineral waters used to a greater extent.

Summary for Northern Atlantic States.

States.	Number of spring localities.	Number of individual springs.	Number of springs analyzed.	Number of spring localities utilized as resorts.	Number of springs used commercially.	Total number of analyses.
Maine	41	49	20	9	11	22
New Hampshire	12	27	8	8	4	8
Vermont	47	74	8	11	7	10
Massachusetts	24	31	7	2	7	8
Rhode Island	6	17	2	0	2	2
Connecticut	16	20	2	2	2	2
New York	200	343	72	25	34	94
New Jersey	13	13	8	1	0	8
Pennsylvania	46	83	28	16	5	33
Total	405	657	155	74	72	187

MAINE.

The mineral springs of Maine belong to the classes of alkaline, saline, and chalybeate waters, the last predominating. Many are sulphureted and a few carbonated. None is thermal, the highest temperature attained, so far as we can learn, being but 50° Fahr. Most of the temperatures range from 40° Fahr. to 46° Fahr.

The amount of mineral matter contained in the waters is usually small and some of the waters would be classed as chemically indifferent. A considerable number are utilized, both commercially and as places of resort. Dr. Goodale's "report on the mineral waters of Maine," in the sixth annual report of Professor Hitchcock to the Maine board of agriculture, made in 1861, is about the only publication in which the mineral waters of the State are treated of systematically. Since that date, however, a number of springs have been discovered, and several of them brought into prominent notice, while others, then used as resorts, have fallen into disuse.

Mineral springs of Maine.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Addison Mineral Spring, Addison, Washington County.	1	1,800	° 45	Alkaline, calcic.	The water is sold.
American Chalybeate Spring, South Auburn, Androscoggin County.	1			Alkaline	Do.
Auburn Mineral Spring, South Auburn, Androscoggin County.	1			do	Do.
Bethel Spring, near Bethel, Oxford County.			42	Chalybeate and sulphureted.	
Boothbay Medicinal Mineral Spring East Boothbay, Lincoln County.	1	300	46	Sulphureted	Used commercially and as a resort.
Chalybeate springs:					
At Andover, Oxford County					
At Biddeford, York County					
At Dixmont, Penobscot County	1				
At Gorham, Cumberland County					
At Harpswell, Cumberland County					
At Newry, Oxford County					
At Topsham, Sagadahoc County					
On Island in Portland harbor, Cumberland County.					
On Upper St. John, near Great Black River, Aroostook County.					
Crystal Spring, 1 mile south of Auburn, Androscoggin County.	1				Water is sold.
Dexter Chalybeate Spring, Dexter, Penobscot County.					
Ebeeme Spring				Carbonated, chalybeate.	
Fryeburg Spring, west part of Fryeburg, Oxford County.			43	do	
Hartford Cold Springs, Hartford, Oxford County.	3		45	Saline	Used commercially and as a resort.
Katahdin Mineral Springs. Katahdin Iron Works, Piscataquis County.	3			Sulpho-chalybeate.	Resort.
Lake Auburn Mineral Spring, North Auburn, Androscoggin County.	1	2,000	40	Alkaline	Used commercially and as a resort.
Lubec Saline Springs, head of Lubec Bay, Washington County.				Saline	
Ludlow Mineral Spring, Ludlow Township, Aroostook County.	1	40			
Machiasport Spring, west part of Machiasport, Washington County.				Saline	
Mount Zircon Spring, Milton Plantation, Oxford County.				do	
North Waterford Springs, northwest of Waterford Village, Oxford County.			40	Sulpho-chalybeate.	
Paradise Spring, near Brunswick, Cumberland County.	1				Very pure water, said to have medicinal effect.
Poland Spring, South Poland, Androscoggin County.	1	490	51	Alkaline	Used commercially and as a resort.
Poland Silica Springs, South Poland, Androscoggin County.	3	480+		do	Do.
Rosicrucian Springs, Rosicrucian, Lincoln County.	3+	800	50	Alkaline, saline	Do.
Samoset Mineral Springs, Nobleborough, Lincoln County.				Alkaline	
Scarborough Mineral Spring, Scarborough, Cumberland County.	1	300	45	Alkaline, chalybeate.	
Sulphur springs:					
In New Limerick Township, Aroostook Co.					
In Saccarappa, Cumberland County					
Near Wells, York County					
Near Mount Pleasant, Oxford Co				Sulpho-chalybeate.	
Summit Mineral Spring, Harrison, Cumberland County.	1	2,280	46	Alkaline	Do.
Togus Spring, near Augusta, Kennebec County.					
Vienna Spring, Vienna, Kennebec Co.					
West Bethel Spring, near West Bethel Station, Oxford County.			42	Carbonated, chalybeate.	Was once a resort.
West Newfield Spring, 2 miles from West Newfield, York County.				Sulphureted	

Analyses of mineral springs in Maine.

Constituents.	Samoset Mineral Springs.	Scarborough Spring.		Summit Mineral Spring.	West Bethel Spring.
	Grs. per gall.[a]	*Grs. in* 10,000.[b]	*Grs. per gall.*[c]	*Grs. per gall.*[d]	*Grs. in* 6,000.[b]
Sodium carbonate				[e]1.402	
Sodium bicarbonate	16.20		1.27		
Magnesium carbonate				0.248	
Magnesium bicarbonate	0.39		0.93		
Calcium carbonate		Trace		0.990	
Calcium bicarbonate	1.09		1.65		
Iron carbonate					2.24
Iron bicarbonate	2.28		1.54		
Potassium sulphate			0.84		
Magnesium sulphate		2.01			
Calcium sulphate	3.07	1.02	0.82		
Iron sulphate					2.23
Aluminium sulphate					0.32
Sodium chloride	1.09	26.05	1.06	0.171	
Potassium chloride		0.52			
Magnesium chloride		2.12			
Magnesium bromide		Trace			
Potash	Trace				
Alumina	Trace		Trace	Trace	
Magnesia					0.10
Lime					0.04
Silica	0.73		0.98	0.980	
Organic matter	Trace			0.238	
Volatile matter					
Loss		0.18			0.99
Total	24.85	31.90	9.09	4.029	5.92

Constituents.	Lubec Saline Springs.	North Waterford Springs.	Paradise Spring.	Poland Silica Springs.	
				Star Spring.	Fountain Head Spring.
	Grs. imp. gall.[f]	*Grs. in* 8,000.[b]	*Grs. per gall.*[a]	*Grs. per gall.*[g]	*Grs. per gall.*[g]
Sodium carbonate			0.36		
Magnesium carbonate			0.06	0.82	
Magnesium bicarbonate					Traces
Calcium carbonate	6.25		0.07	2.33	
Calcium bicarbonate					1.39
Iron carbonate	2.50			2.24	
Sodium sulphate	27.98	0.42			
Potassium sulphate				0.90	0.12
Calcium sulphate	11.21		0.06		
Iron sulphate		4.01			
Aluminium sulphate		2.73			
Sodium chloride	199.00		0.02	4.85	1.51
Potassium chloride			0.04		
Magnesium chloride	62.84				
Calcium chloride	12.72				
Loss					
Iron oxide			Trace.		
Alumina				[h]0.32	
Magnesia		.09			
Lime					
Silica			0.38	0.58	0.93
Organic matter				2.25	
Total	322.50	7.25	0.09	14.29	3.93

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[a] Henry Carmichael, analyst.
[b] George L. Goodale, analyst (1861).
[c] S. Dana Hayes, analyst (1876).
[d] F. L. Bartlett, analyst (1875).
[e] With potassium carbonate.
[f] C. T. Jackson, analyst.
[g] F. L. Bartlett, analyst.
[h] With iron.

Analyses of mineral springs in Maine—Continued.

Constituents.	Poland Spring.		Rosicrucian Springs.		Addison Mineral Spring.
			Rosicrucian Spring.	Ashburton Spring.	
	Grs. per gall.[a]	*Grs. per gall.*[b]	*Grs. per gall.*[c]	*Grs. per gall.*[d]	*Grs. per gall.*[d]
Sodium carbonate	0.09	0.13			
Sodium bicarbonate			7.48	0.94	0.443
Magnesium carbonate	0.30	0.54			
Magnesium bicarbonate			1.04	0.29	1.122
Calcium carbonate	1.36	1.23			
Calcium bicarbonate			2.67	0.47	2.646
Iron carbonate	Trace				
Iron bicarbonate					1.651
Sodium sulphate			0.95		0.266
Potassium sulphate	0.18	0.16	2.31	0.19	0.601
Calcium sulphate					0.524
Sodium chloride	0.47	0.26	19.86	0.20	0.887
Sodium iodide			Trace		
Sodium bromide					
Calcium fluoride	Trace				
Lithia	Trace				
Iron oxide		Trace	0.07	Trace	
Alumina	Trace	Trace	0.03		Trace
Silica	1.07	1.12			Trace
Silicic acid in solution			1.02	0.96	
Organic matter	0.28	0.23			
Volatile matter					
Total	3.75	3.67	35.43	3.05	8.140

Constituents.	Boothbay Medicinal Spring.	Ebeeme Spring.	Fryeburg Spring.	Hartford Cold Springs.	Lake Auburn Mineral Spring.
	Grs. per gall.[e]	*Grs. in 6,000.*[f]	*Grs. in 6,000.*[f]	*Grs. per gall.*[g]	*Grs. per gall*[h]
Sodium bicarbonate					1.20
Magnesium bicarbonate	1.01			1.92	0.30
Calcium bicarbonate	3.33			23.27	0.43
Iron carbonate		5.62	2.10		
Iron bicarbonate	2.73			0.31	
Potassium sulphate	1.99			4.05	0.18
Calcium sulphate		[i]2.01			
Iron sulphate	0.81	1.23	1.21		
Sodium chloride	1.88			12.39	0.26
Potassium chloride				1.07	
Magnesium chloride				0.97	
Iron oxide					Trace
Alumina	Trace			0.24	Trace
Magnesia		0.11			
Lime			0.10		
Silica	0.64			0.46	
Silicic acid in solution					1.41
Organic matter	Trace				
Total	12.39	8.97	3.41	44.68	3.78

Constituents.	American Chalybeate Spring.	Auburn Mineral Spring.
	Grains per gall.[j]	*Grains per gall.*[j]
Calcium carbonate	3.935	0.814
Magnesium carbonate	1.102	0.128
Iron carbonate	0.737	
Potassium sulphate	0.844	0.229
Iron sulphate	0.320	
Sodium chloride	0.334	0.176
Iron		Trace
Alumina	0.648	Trace
Silica		0.683
Organic matter	0.242	0.242
Total	8.162	2.272

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[a] F. L. Bartlett, analyst (1879).

[b] C. F. Chandler, analyst.

[c] S. Dana Hayes, analyst (1877).

[d] S. Dana Hayes, analyst.

[e] F. L. Bartlett, analyst (November 15, 1883).

[f] George L. Goodale (1861).

[g] Analyzed 1882.

[h] S. Dana Hayes, analyst (1879).

[i] With alumina.

[j] F. L. Bartlett, analyst (1878).

NEW HAMPSHIRE.

Mr. G. W. Hawes, in Hitchcock's Geology of New Hampshire, says there are a large number of mineral springs in various parts of the State and that chalybeate waters are the most common. He mentions those of Pittsfield, Amherst, and Unity as the best known. Walton's book gives four localities. Pepper's list includes nine. In the present catalogue the number is increased to eleven.

A fair proportion are utilized commercially or as resorts, although as a rule the springs are not highly mineralized. In this respect they agree with most of the springs in the other New England States.

Mineral springs of New Hampshire.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Abenaquis Springs, Walpole, Cheshire County.	......	....	....	....	
Amherst Soda Springs, two miles from Amherst, Hillsborough County.	2	....	....	....	Resort.
Birchdale Springs, near Concord, Merrimack County.	3	....	....	Calcic, chalybeate.	Used commercially and as a resort.
Bradford Mineral Spring, Bradford, Merrimack County.	1	2,000	46	Carbonated, saline.	Used commercially to a limited extent and as a resort.
Charlestown Springs, Charlestown, Sullivan County.	......	....	....	Chalybeate	Unimportant.
Milford (Ponemah) Springs, Milford, Hillsborough County.	4	440	....	Chalybeate, &c.	Used commercially and as a resort.
Moultonborough Mineral Spring, Moultonborough, Carroll County.	1	200	....	Chalybeate	Used commercially prior to 1882.
Pine Grove or Amherst Mineral Spring, Amherst, Hillsborough County.	1	60	....	Calcic, chalybeate.	Resort.
Sulpho-Chalybeate Spring, half mile northeast of Pittsfield, Merrimack County.	......	....	....	....	
Unity or Unitoga Springs, East Unity, Sullivan County.	10	500+	48	Alkaline or calcic saline. (?)	Do.
White Mountain Mineral Spring, Conway, Carroll County.	......	....	....	Alkaline.........	Used commercially and as a resort.
Yacum Spring, Goffstown Centre, Hillsborough County.	1	120	48	Chalybeate	Resort.

Analyses of mineral springs in New Hampshire.

Constituents.	Milford Springs.			
	Iron Spring.	Magnesia Spring.	Ponemah Spring.	Milford Spring.
	Grains per gall.[a]	*Grains per gall.*[a]	*Grains per gall.*[b]	*Grains per gall.*[a]
Sodium carbonate	....	....	0.24	....
Calcium carbonate	....	2.00	0.34	....
Magnesium carbonate	0.40	....	....	....
Sodium chloride	....	1.00	0.20	0.90
Sodium sulphate	0.40	....	0.37	0.60
Potassium sulphate	....	....	0.07	1.80
Calcium sulphate	....	1.04	....	....
Magnesium sulphate	....	2.00	....	....
Iron sulphate	1.04	Trace	....	1.00
Iron oxide	....	....	0.09	....
Silica	....	Trace	1.24	1.01
Alumina	[c]1.04	....	....	....
Magnesia	....	....	Trace	....
Water	....	....	0.48	....
Carbonic acid	In excess	Present	Present	Present
Total	2.88	6.04	3.03	5.31

[a] George E. Sewell, analyst (1882). [b] John M. Ordway, analyst (1883). [c] With soda.

Analyses of mineral springs in New Hampshire—Continued.

Constituents.	Birchdale Springs—Concord Spring.	White Mountain Mineral Spring.	Pine Grove Mineral Spring.	Unity Springs—Iron Spring.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per imp. gallon.*[c]	*Grains per gallon.*[d]
Sodium carbonate			0.28	
Sodium bicarbonate	0.19			0.22
Calcium carbonate			5.66	
Calcium bicarbonate	2.09	0.65		4.17
Magnesium carbonate		0.11	1.47	
Magnesium bicarbonate	0.84			0.86
Iron carbonate		Trace	1.80	
Iron bicarbonate	0.37			
Sodium chloride	0.38	0.47	0.87	0.42
Sodium sulphate	0.26			
Potassium sulphate	0.07	0.18	0.35	0.10
Calcium sulphate			1.63	0.81
Sodium phosphate	0.01			
Iron oxide				2.16
Silica	0.92	0.67	0.09	
Alumina	0.12	Trace		0.04
Organic matter	0.67			
Crenic acid			3.87	2.89
Carbonic acid			Undetermined	
Total	5.92	2.08	15.52	11.67

[a] C.F. Chandler, analyst (1873).
[b] F. L. Bartlett, analyst (1882).
[c] James A. Babcock, analyst.
[d] S. Dana Hayes, analyst (1874).

VERMONT.

In general the springs of Vermont are much like those of Maine and New Hampshire, except that they usually contain a larger proportion of mineral matter. This may be due in part to the fact that the rocks through which the springs rise belong more frequently to the sedimentary series. Sulphureted springs are most abundant. Of the springs whose character is indicated on the list, nearly all are included in this class. Calcareous tufa is found in connection with many of the springs.

Prof. Edward Hitchcock, in a letter to Prof. C. B. Adams,[1] in 1846, describes a thermal spring at Bennington. He does not give the temperature, but compares it with the spring at Williamstown, Mass., which is only slightly thermal. Clarendon, Alburgh, and Highgate springs appear to be the best known springs, although others are also largely used. The Clarendon springs are said to have been used medicinally in 1776, Alburgh has been a place of resort since 1816, and the use of Highgate dates back to 1840.

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[1] Second Annual Report on Geology of Vermont, p. 250. Burlington, 1846.

Mineral springs of Vermont.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alburgh Springs, Alburgh Springs, Grand Isle County.	3	45	° 53	Saline, sulphureted.	Used commercially and as a resort.
Beardsley Iron Springs, Alburgh Springs, Grand Isle County.	3	....	....	Chalybeate and sulphureted.	Do.
Barre Mineral Springs, Barre, Washington County.	2	....	....	Sulphureted	Resort.
Bennington Thermal Spring, Bennington, Bennington County.	......	......	....	....	
Berkshire Mineral Springs, West Berkshire, Franklin County.	2	....	....	Sulphureted	
Bower Spring, near Hartland, Windsor County.	1	....	....	Sulphureted	Was a resort at one time.
Brunswick White Sulphur Springs, Brunswick, Essex County.	6	1,000	48	Chalybeate and sulphureted.	Used commercially and as a resort.
Central Spring, Sheldon, Franklin County.	......	....	....	....	
Champlain Spring, near Highgate, Franklin County.	1	160	....	....	Little used at present.
Chester Medicinal Spring, near Chester, Windsor County.	......	....	...	Sulpho-chalybeate.	
Clarendon Mineral Springs, Clarendon Springs, Rutland County.	3	640	46 to 50	Carbonated, calcic.	Used commercially and as a resort.
Elgin Spring. Panton, Addison County.	1	....	46	Saline..........	Used commercially.
Guilford Mineral Springs, Guilford Centre, Windham County.	8	....	....	Saline, chalybeate.	Five or six years ago used commercially and as a resort.
Haynes Mineral Spring, Hardwick, Caledonia County.	1	....	....	....	Was once a resort.
Harrington Springs, 2 miles north of Quechee, Windsor County.	......	....	....	....	
Highgate Spring, Highgate Springs, Franklin County.	......	....	....	Sulpho-saline ...	Resort.
Iodine Springs, near Berkshire, Franklin County.	6	....	....	Sulphureted	
Lunenburgh Chalybeate Mineral Spring, Lunenburgh, Essex County.	1	65	48	Chalybeate	Resort; also sold to some extent.
Martin's Spring, north part of Shaftsbury, Bennington County.	......	....	....	....	Unimproved; once had considerable reputation.
Middletown Mineral Springs, Middletown Springs, Rutland County.	8	....	....	....	Used commercially and as a resort.
Mineral springs:					
Near Back, or Pilotsburg, North Hero, Grand Isle County.	......	....	....	....	
In South Hero, Grand Isle County,	2	....	....	....	
West of Stowe, Lamoille County...	......	....	....	....	
In Williamstown, Orange County..	......	....	....	....	
In Cabot, Washington County	2	....	....	Iron and sulphur	Unimportant.
In Vernon, Windham County......	......	....	....	....	
Missisquoi Spring, 8 miles south of Sheldon, Franklin County.	......	....	....	....	Used commercially.
Newbury Springs (Montebello Springs), Newbury, Orange County.	2	......	48 to 55	Sulphureted, calcic, and chalybeate.	Resort.
North Wolcott Spring, North Wolcott, Lamoille County.	1	120+	....	....	Was once a resort.
Plainfield Spring, Plainfield, Washington County.	1	....	....	Sulphureted	Has been a resort.
Sanderson Spring, 8 miles south of Woodstock, Windsor County.	......	....	....	....	Used medicinally to a limited extent.
Sheldon Spring, Sheldon, Franklin County.	1	500	45	Alkaline, saline.	Used commercially and as a resort.
Sudbury Mineral Springs, Sudbury, Rutland County.	......	....	....	....	
Sulphur springs:					
Northeast of Orwell Centre, Addison County.	......	....	....	....	Has local reputation.
Two miles west of Tunbridge, Orange County.	......	....	....	....	

Mineral springs of Vermont—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Sulphur springs—Continued.			°		
One mile south of West Randolph, Orange County.					
Near Hartland Four Corners, Windsor County.					
Northeastern part of Arlington, Bennington County.					
Near Andover, Windsor County					
Western part of Sudbury, Rutland County.					Local reputation.
Near Chelsea, Orange Co	3				
Western part of Craftsbury, Orleans County.					
Northeast of Stowe, Lamoille Co.					
Near East Montpelier, Washington County.	1				Not important.
Vermont Springs, Sheldon, Franklin Co.					
Warren Springs, eastern part of Warren, Washington County.					
Welden Springs, St. Albans, Franklin County.					Unimproved and unused.

Analyses of mineral springs in Vermont.

Constituents.	Alburgh Springs.	Clarendon Springs.	Guilford Mineral Springs.		Middletown Springs—Spring No. 1.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[a]	*Grains per gallon.*[c]	*Grains in 1 cubic ft., about 7 gallons.*[d]
Sodium carbonate			2.40		25.74
Magnesium carbonate			0.60		10.12
Calcium carbonate		3.02	15.18		26.81
Iron carbonate			2.99		10.68
Manganese carbonate					9.41
Magnesium sulphate		[e]2.74			
Sodium sulphate	7.11				
Potassium sulphate	[f]9.50				
Calcium sulphate					1.15
Sodium chloride	8.76		2.41		1.74
Potassium chloride					[e]10.48
Magnesium chloride	5.02				
Calcium chloride	[g]4.81				
Soda				0.76	
Potash				1.11	
Magnesia				1.51	
Lime				8.74	
Ammonia				Trace	
Ferrous oxide				0.85	
Alumina				Trace	0.67
Sodium				0.58	
Chlorine				0.88	
Sulphuric acid				0.69	
Carbonic acid (combined)				9.17	
Silicic acid				0.99	
Insoluble silica			[h]0.60		
Insoluble matter	0.80				
Crenic acid				1.64	
Organic matter			5.60		
Organic soil acid	2.00				
Loss			0.40		
Total	38.00	5.76	30.18	26.92	96.75
Gases.		*Cubic inches.*			
Carbonic acid		46.16			
Nitrogen		9.63			

[a] C. T. Jackson, analyst (1868).

[b] A. A. Hayes, analyst.

[c] A. A. and S. Dana Hayes, analysts (1869).

[d] Peter Collier, analyst.

[e] With calcium chloride.

[f] With potassium sulphide.

[g] With calcium carbonate.

[h] With traces of nitrate of potash.

Analyses of mineral springs in Vermont—Continued.

Constituents.	Highgate Springs.		Montebello or Newbury Springs.		Sheldon Spring.
	Champlain Spring.	Name unknown.			
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate	1.22	13.70	0.40		
Potassium carbonate	3.67				
Magnesium carbonate	1.22	5.83	0.24		
Calcium carbonate	1.02	1.40	17.60		
Ammonium carbonate	Trace				
Iron carbonate				45.04	
Potassium nitrate			0.40		
Sodium sulphate		2.45	0.24	17.12	
Calcium sulphate				13.20	
Iron sulphate				48.60	
Iron phosphate			0.40		
Sodium chloride	0.17	23.44	0.32		
Potassium chloride	0.74				
Magnesium chloride				34.00	
Sodium sulphide			0.32		
Soda					4.01
Potash					0.09
Magnesia					0.17
Lime					1.08
Ammonia					Trace
Ferrous oxide	0.03		Trace		0.01
Sodium					0.15
Chlorine					0.16
Sulphuric acid					0.51
Carbonic-acid (combined)					2.11
Silicic acid	0.81				4.59
Insoluble silica			8.80		
Organic matter			[f]0.24		2.87
Crenic acid	0.90				
Loss			8.64		
Total	9.78	46.82	37.60	157.96	15.75

[a] A. A. Hayes, analyst.

[b] T. Sterry Hunt, analyst (1867).

[c] Professor Hall, analyst.

[d] I. P. Dix, analyst.

[e] S. Dana Hayes, analyst (1867).

[f] With ammonia.

MASSACHUSETTS.

The State of Massachusetts is not remarkable for the occurrence of mineral springs. The list contains twenty-one localities. In most lists only two are included, viz, Hopkinton Springs and the Berkshire Soda Springs. The former was once an important place of resort, but at present its springs are not utilized to any considerable extent. Brookfield and Shutesbury were also once much frequented.

Professor Hitchcock, in the reports on the geology of Massachusetts made in 1833 and 1849, says that chalybeate springs are common throughout the State, occurring in nearly every town, usually rising in low ground containing bog iron. Many of these springs have a local reputation and a few are used commercially. Such analyses as have been made show that as a rule the waters are not highly mineralized. A mineral spring near Williamstown is said to be slightly thermal and in the extreme southwestern part of the State, near Mount Washington, there is reported to be another similar spring.

Mineral springs of Massachusetts.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Allandale Springs, West Roxbury, Suffolk County.	2	1,250	55 to 60	Alkaline	Used commercially.
Berkshire Soda Springs, near Great Barrington, Berkshire County.	2				Do.
Bethlehem Spring, Worcester Co., near Braggville.	1			Alkaline	Do.
Brookfield Spring, Brookfield, Worcester County.				Carbonated chalybeate.	
Chalybeate springs:					
South Hadley, Hampshire County	2	100	60		Unimproved.
Deerfield, Franklin County					
Crystal Mineral Springs, Stoneham, Middlesex County.	2		45 to 60	Slightly chalybeate.	Used commercially.
Coldbrook Mineral Springs, Coldbrook Springs, Worcester County.	2			Sulpho-chalybeate.	Resort.
Commonwealth Mineral Spring, Waltham, Middlesex County.	1	600	48	Alkaline	Used commercially.
Echo Grove Mineral Spring, Lynn, Essex County.	1			Carbonated	Used commercially and as a resort.
Everett Crystal Spring, Everett, Middlesex County.	1	3,000		Calcic-saline	Used commercially.
Hopkinton Springs, Hopkinton, Middlesex County.				Carbonated chalybeate.	Was once a resort.
Mendon Mineral Springs, Mendon, Worcester County.				Carbonated	
Mineral springs:					
Adams, Berkshire County					
Pittsfield, Berkshire County					
One mile from South Hadley, Hampshire County.					Once used as a resort.
West Medway, Norfolk County					
Springfield, Hampden County					
Five miles south of Williamstown, Berkshire County.			Tepid.	Contains nitrogen gas.	
Near Mount Washington, Berkshire County.			46		
One or two miles south of Hinsdale, Berkshire County.				Sulphureted	
Mineral Spring (pool), Shutesbury, Franklin County.	1				Once used as a resort.
Mount Mineral Springs, Shutesbury, Franklin County.	3				Do.
Sulphur Springs, two miles northeast of North Blandford, Hampden Co.					

Analyses of mineral springs in Massachusetts.

Constituents.	Allandale Spring.	Bethlehem Spring.	Echo Grove Mineral Spring.	
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]
Sodium carbonate	0.03	0.27	....	0.79
Sodium bicarbonate	....	....	0.10	....
Magnesium carbonate	0.40	0.55	....	1.43
Magnesium bicarbonate	....	....	0.76	....
Calcium carbonate	0.70	0.60	....	4.27
Calcium bicarbonate	....	....	1.38	....
Iron carbonate	0.02	0.07	....	....
Lithium bicarbonate	....	0.08	....	....
Sodium sulphate	0.37	0.33	....	....
Potassium sulphate	0.15	0.14	0.41	0.07
Sodium chloride	0.38	0.31	0.99	1.18
Silicic acid in solution	....	....	0.37	0.67
Silica	0.57	0.52	....	....
Iron	....	....	Trace	Trace
Alumina	....	....	Trace	....
Organic matter	0.29	0.27	....	No trace
Water of hydration	0.39	0.39	....	....
Total	3.30	3.48	4.01	8.41

Constituents.	Coldbrook Springs.		Everett Crystal Spring.	Commonwealth Spring.
	No. 1, sulphur spring.	No. 2, iron spring.		
	Grains per gallon.[e]	*Grains per gallon.*[e]	*Parts per 1,000.*[f]	*Grains per gallon.*[e]
Sodium bicarbonate	....	....	....	0.501
Magnesium bicarbonate	....	....	....	0.181
Calcium bicarbonate	....	....	0.0213	0.447
Potassium sulphate	....	....	....	0.611
Calcium sulphate	....	....	0.0350	....
Nitrates	....	....	Trace	....
Sodium chloride	....	....	0.0060	0.340
Magnesium chloride	....	....	0.0342	....
Silicic acid in solution	1.27	1.11	....	0.370
Silica	....	....	0.0160	....
Iron oxide	(g)	0.82	....	....
Iron	....	....	Trace	Trace
Alumina	....	....	....	
Lime	0.31	....	....	....
Magnesia	0.26	....	....	....
Potash and soda	1.48	0.50	....	....
Chlorine	0.41	....	....	....
Sulphur	0.70	0.22	....	....
Sulphuric acid			....	....
Ammonia	(g)	....	....	....
Albuminoid ammonia	....	....	[h]0.0001	....
Crenic acid	2.20	1.20	....	....
Organic matter	[g]0.69	0.31	....	....
Loss			....	....
Water of hydration	24.28	16.64	....	....
Volatile matter (on ignition)	....	....	0.0530	....
Total	31.60	20.80	0.1656	2.450

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[a] William Ripley Nichols, analyst.

[b] E. Cornell Esten, analyst (1885).

[c] S. Dana Hayes, analyst (1879).

[d] Charles R. Fletcher, analyst (1880).

[e] A. A. Hayes, analyst.

[f] Samuel Cabot, jr., analyst (1882).

[g] Iron oxide, ammonia, loss, organic matter, all equal 0.69.

[h] With free ammonia.

RHODE ISLAND.

The record of mineral springs for Rhode Island is somewhat meager and so far as we can learn the springs are of comparatively little importance. It is said that, in connection with the spring near Pawtucket, there was in operation for a number of years an extensive water-cure and medical establishment.

There may possibly be a few springs in the State that have escaped notice, and if so the waters are likely to be somewhat chalybeate.

Mineral springs of Rhode Island.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Cranston Mineral Spring, on Sockanosset Hill, Cranston Township, Providence County.	......	....	......	Chalybeate	Unimproved.
Cumberland Spring, Cumberland Hill, Providence County.	......	....	......	....	
Darling's Mineral Springs, near Pawtucket, Providence County.	......	....	......	Chalybeate and sulphureted.	Once a water cure and sanitarium.
Holly Spring, 2 miles east of Woonsocket, Providence County.	1	180	......	Alkaline........	Water is sold.
Ochee Springs, Johnson Township, 3 miles from Providence, Providence County.	12	500	45	Alkaline, calcic.	Water is bottled and sold.
Warwick Neck Mineral Springs, Warwick Neck, Kent County.	......	....	......	Chalybeate	Unimproved.

Analyses of mineral springs in Rhode Island.

Constituents.	Ochee Springs.	Holly Spring.
	Grains per gallon.[a]	*Grains per gallon.*[b]
Calcium carbonate	3.198	0.43545
Magnesium carbonate	1.126	0.24516
Sodium sulphate	0.414	....
Calcium sulphate	0.443	0.37125
Potassium sulphate	0.881	....
Sodium chloride	0.566	0.34439
Potassium chloride	....	Trace
Silica	....	0.60707
Alumina Iron oxide	0.747	0.03619
Insoluble mineral matter	0.583	....
Organic matter Volatile matter	0.876	0.46697
Undetermined	0.155	....
Loss	....	0.00352
Total	8.989	2.51000

[a] John K. Appleton, analyst (1880).

[b] Edwin E. Calder, analyst (1883).

CONNECTICUT.

The mineral springs of Connecticut are comparatively unimportant, at least in point of number, and, so far as known, they are feebly mineralized. They are mainly weak chalybeates, occurring under the same circumstances as do those of Massachusetts, in deposits of bog-iron ore or in connection with iron pyrites. Some are also feebly sulphureted. Although the majority are unimproved and but few are used commercially, many have considerable local reputation. Prof. C. W. Shepard in 1837 speaks of the springs at Stafford as being the most important in the State, and this is still the case. This locality is the only one given by Walton. Many of the places once resorted to are now abandoned. The present list is made up from Professor Shepard's report, supplemented by information acquired by correspondence with various persons in the State.

Mineral springs of Connecticut.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Bald Hill Spring, Portland, Middlesex County.				Chalybeate	Unimproved and unimportant.
Chalybeate springs:					
Cromwell, Middlesex County					Improved about 50 years ago; unimproved now.
Two miles east of South Kent, Litchfield County.					
Four miles west of Litchfield, Litchfield County.					
Collins Hill Spring, Portland, Middlesex County.					Unimproved and unimportant.
Holbrook Mineral Spring, Lebanon, New London County.				Sulphureted	Improved 15 years ago.
Kenyon's Mill Spring, Colchester, New London County.					Used locally.
Mineral Springs, North Woodstock, Windham County.	4			Sulphureted chalybeate, &c.	Once a resort.
Oxford Spring, Oxford, New Haven County.				Chalybeate	Used commercially.
The Pool, North Haven, New Haven County.	1	480	50	do	Has local reputation.
The Pool, Salisbury, Litchfield County.	1				Once had a local reputation.
The Pool, Suffield, Hartford County	1			Sulphureted	Was a resort 30 years ago; has local reputation.
Stafford Springs, Stafford Springs, Tolland County.	2	55+	34 to 46	Chalybeate	Resort; most important in the State.
Stark Mineral Spring, Bozrah, New London County.	1	200	46	Saline	Used commercially and as a resort.
Strong's Mill Spring, Colchester, New London County.	1			Chalybeate and sulphureted.	Has local reputation.
Sulphur Spring, Nepaug, Litchfield County.	1				Unimproved.

Analyses of mineral springs in Connecticut.

Constituents.	Oxford Spring.	Stark Mineral Spring.
	Grs. per gall. [a]	*Grs. per gall.* [b]
Sodium bicarbonate		0.29
Potassium bicarbonate		0.10
Magnesium bicarbonate		0.33
Calcium bicarbonate		1.23
Iron carbonate	0.91	
Iron bicarbonate		0.06
Sodium sulphate	0.49	0.18
Potassium sulphate	Trace	
Lithium sulphate	Trace	
Magnesium sulphate	0.62	
Calcium sulphate	1.16	
Sodium chloride	0.34	0.33
Silicic acid		0.85
Silica and insoluble matter	1.33	
Organic matter	1.27	
Loss	0.10	
Total	6.22	3.37

[a] George F. Barker, analyst (1873). [b] S. W. Johnson, analyst (1880).

NEW YORK.

New York is distinguished among her sister States for the number of her mineral springs. On the list she is credited with a greater number of localities than any other State, which may be due to the fact that attention has been more drawn to the subject of mineral springs in New York than in most other States, probably on account of the commercial success of the Saratoga Springs. It is due also, in part, to the fact that the springs have been pretty thoroughly studied and so many of them subjected to chemical examination. The list given by Professor Beck in Vol. III of the New York Geological Reports was very complete for the State at the time it was published (1842). Since then many springs have been discovered. Some considered unimportant at that time have since been developed, while others used as resorts have been abandoned. The springs are of great variety. The majority of them are sulphureted. As to the solid mineral contents, saline and chalybeate springs predominate. The highest temperature reached by any of the springs is at Lebanon, where the thermal spring attains 75° F. Several of the springs at Saratoga and Ballston have temperatures that exceed the mean annual temperatures of those places, and are, therefore, in a strict sense, thermal springs.

Another point of interest in relation to the New York mineral springs is the occurrence of springs containing free sulphuric acid, as springs of this class are somewhat rare. The most celebrated spring of this class in New York is probably the Oak Orchard spring.

The Saratoga Springs are the most widely known of American springs and have many namesakes in all parts of the United States, being in all probability the first mineral springs of the country to be improved as a place of resort, the first hotel for the accommodation of visitors having been opened there in 1774.

Mineral springs of New York.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Adirondack Mineral Springs, Whitehall, Washington County.	2	200	° 88	Chalybeate	Used commercially.
Albany Artesian Well (500 feet), Albany, Albany County.	1			Saline	
Auburn Spring, 4 miles west of Auburn, Cayuga County.	1			Sulphureted	Has a local reputation and is sold to small extent.
Avon Sulphur Springs, Avon, Livingston County.	4	7,660	50	do	Used commercially and as a resort.
Ballston Spa Springs, Ballston, Saratoga County.					Resort.
Artesian Lithia Spring	1	5	52	Saline	Used commercially.
Franklin Spring	1		52	do	
Iron Spring	1	4,000		do	
Sans Souci Spring	1			do	
United States Spring	1		50	do	
Washington Lithia Well	1		49	do	Do.
Barton Sulphur Spring, near Waverly, Tioga County.					
Byron Acid Spring, Byron, Genesee Co.				Acid	
Cairo White Sulphur Springs, Cairo, Greene County.				Sulphureted	Resort.
Calcic springs:					
Near Sempronius, Cayuga County.					
Near Chateaugay, Franklin County.					
On Otsquago Creek, Stark Township, Herkimer County.					
Near Starkville, Herkimer County.					
At Caledonia, Livingston County.					
Near Cartersville, Monroe County.					Unimproved.
In southwestern part of Wheatland Township, Monroe County.					Do.
In Cather's Cave, near Niagara Falls, Niagara County.					
Near Syracuse, Onondaga County.					
At Manlius Centre, Onondaga County.					
At Onondaga, Onondaga County					
North of Otisco Lake outlet, Onondaga County.					
At Schoharie, Schoharie County.					
Four miles northwest of Gouverneur, Saint Lawrence County.					
Near Ithaca, Tompkins County.					
In Washington County					
Canoga Springs, Canoga, Seneca Co.					
Cayuga Mineral Spring, 2½ miles north of Cayuga, Cayuga County.	1	50			Used commercially.
Chalybeate springs:					
Five miles northwest of Auburn, Cayuga County.					Used locally for medicinal purposes.
Four or five miles from West Troy, Albany County.					
South of Canaan Centre, Columbia County.					
Livingston, Columbia County.					
Near Sidney Plains, Delaware Co.					
Two miles from Bloomville, Delaware County.					
Three miles above Walton, Delaware County.					
Near Upton Pond, Dutchess County					
Near Kline's Corners, Dutchess Co.					
Near Williamsville, Erie County					
Two miles north of Elba, Genesee County.					
North part of Warren Township, Herkimer County.					
Bethel, in Stark Township, Herkimer County.					
South part of Pittsford Township, Monroe County.					Unimproved.

Mineral springs of New York—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Chalybeate springs—Continued.			°		
Near Lewiston, Niagara County					
Van Buren Township, Onondaga Co.					
Near West Point, Orange County					
Shawangunk Mt., Orange County					
Near Sand Lake, Rensselaer Co					
In Richmond County					
Between West Neck and Lloyd's Neck, Suffolk County.					
Near North Blenheim, Schoharie Co.					
In Steuben County					
Three miles from Sag Harbor, Suffolk County.					
Horton's Point, Suffolk County					Small and unimportant.
Hudson's Point, Riverhead, Suffolk County.					
East Hampton, Suffolk County					
At Little Cow Harbor, Suffolk Co.					Unimportant.
At North Salem, Westchester Co					
Chappaqua Spring, Chappaqua, Westchester County.					
Cherry Valley Phosphate Spring, Cherry Valley, Otsego County.	1	10			Not used at present.
Cherry Valley Springs, Cherry Valley, Otsego County.	2			Sulphureted	
Chittenango White Sulphur Springs, Chittenango, Madison County.	3		49½	do	Resort.
Chlorine Springs, Syracuse, Onondaga County.	5	2,000	49	Saline	Used commercially and as a resort.
Clifton Springs, Clifton Springs, Ontario County.	3+		54	Sulphureted	Resort.
Clinton Spring, Cliff street, New York, New York County.					
Columbia White Sulphur Springs, 4 miles north of Hudson, Columbia Co.	4		55	Saline, sulphureted.	Do.
Crystal Springs, Crystal Spring, Yates County.	6	1,250+	48		Do.
Dansville Springs, Dansville, Livingston County.	4	1,000		Alkaline, calcic.	Sanitarium and resort.
Darien Mineral Spring, Darien Centre, Genesee County.	1	40?		Acid	Used commercially.
Darrow Spring, south of Baldwinsville, Onondaga County.	1			Calcic, sulphur	Has a local reputation.
Deep Rock Springs, Oswego, Oswego County.	2		50	Sulphureted, saline.	Used commercially and as a resort.
Diamond Rock Mineral Well, Williamson, Wayne County.	1	30	44	Sulpho-saline	Do.
Doxtatter's Mineral Well (Longmuir's Well), Rochester, Monroe County.	1		52	Saline, sulphureted.	Used for bathing.
Dryden Springs, half mile west of Dryden, Tompkins County.			48 to 54	Chalybeate and sulphureted, saline.	Resort.
Elkhorn Springs, north of Manlius Village, Onondaga County.	8		50	Saline, sulphureted.	Local resort.
Excelsior Spring, Syracuse, Onondaga County.	1	1,000	48	Saline	Used commercially and as a resort.
Fairport Mineral Springs, Fairport, Monroe County.	2			Sulphureted, &c.	Has a local reputation.
Florida Springs, Florida Township, Montgomery County.	2		43	Sulphureted	Local resort.
Franklin Springs, Cowlesville, Wyoming County.	1		40		Resort.
Grove Springs, near Hammondsport, Steuben County.					
Halleck's Spring, near Westmoreland, Oneida County.	1			Saline	Was improved and used as a resort about 1838 to 1840, but is now unimproved.
Harrowgate Springs, Rensselaer County, 3 miles from Albany.				Sulphureted	
Kingsley Springs, near Marion, Wayne County.	3		40	Saline?	Unimproved.
Lebanon Thermal Spring, Lebanon Springs, Columbia County.	1	30,000	75	Chalybeate	Used commercially and as a resort.

Mineral springs of New York—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Lockport Mineral Spring, 1½ miles north of Lockport, Niagara County.	......	....	....	Saline	Unimproved, but used by residents of Lockport.
Madrid Springs, Madrid Springs, Saint Lawrence County.	......	....	....	....	Unimproved at present.
Massena or Saint Regis Springs, Massena, Saint Lawrence County.	2	700+	45	Saline, sulphureted.	Used commercially and as a resort.
Messena Sulphur Springs, 3 miles east of Syracuse, Onondaga County.	3	5	50	Sulphureted	
Mineral Springs, 1½ miles northwest of Cayuga, Cayuga County.	......	....	....	....	Has local reputation and is sold.
Mineral Springs, Mineral Springs, Schoharie County.	2	120	44	....	Unimproved at present; was once a resort.
Mineral springs:					
At Watervleit Centre, Albany County.	......	....	....	Sulphureted, chalybeate, carbonated.	
At Montezuma, Cayuga County...	......	....	....	Saline..........	Unimportant.
Near Crown Point, Essex County..	......	....	....	....do	
Northwestern part of Columbia Township, Herkimer County.	......	....	....	....	
Two miles northeast of Pittsford, Monroe County.	......	....	....	Saline, sulphureted.	Sold to some extent.
North of Elbridge, Onondaga Co...	1	....	....	Saline?	Unimproved.
At Quaker Springs, Saratoga Co...	......	....	....	Sulphureted	Do.
Monroe Springs, 5 miles from Rochester, Monroe County.	......	....	....	....do	
Nanticoke Sulphur Springs, near Lamb's Corners, Broome County.	......	....	....	....	
Nunda Mineral Springs, Nunda, Livingston County.	3	30	....	Saline	Resort and water is sold.
Oak Orchard Acid Springs, Alabama, Genesee County.	8	....	....	Acid and chalybeate.	Used commercially.
Pitcher Springs, Pitcher Springs, Chenango County.	......	....	....	Sulphureted	
Pittsford Sulphur Springs, Olcott's farm, northwest part of Pittsford Township, Monroe County.	......	....	....	....do	Once a resort.
Reid's Mineral Spring, South Argyle, Washington County.	1	8	....	Carbonated, saline.	Local resort.
Richfield Springs, Richfield Springs, Otsego County.	3	....	47	Sulphureted, chalybeate, and saline.	Resort.
Riga Mineral Springs, Riga, Monroe County.	......	....	....	Carbonated, chalybeate.	
Sauquoit Sulphur Spring, near Sauquoit, Oneida County.	1	4	....	Saline	Unimproved.
Saratoga Springs, Saratoga County	......	....	....	....	Resort.
Champion Spring..................	1	2,500	49	Saline carbonated	Used commercially.
Columbian Springs	4	....	55	....do	Do.
Congress Spring...................	......	....	51	....do	Do.
Crystal Springs...................	6	129	....	....	
Ellis Spring	1	....	....	....	Surface spring.
Empire Spring	......	....	....	Saline carbonated	Used commercially.
Eureka Spring	......	....	....	....	Not in general use at present.
Excelsior Spring	1	83	45	Saline carbonated	Used commercially.
Flat Rock Spring..................	......	....	....	....do	
Geyser Springs....................	3	900+	46	....do	Do.
Hamilton Spring	......	....	49½	....	
Hathorn Spring	......	....	....	Saline carbonated	Do.
High Rock and Apollis Springs ...	2	1,000	....	....do	Do.
Indian Encampment Spring	......	....	....	....	Abandoned.
Lake Sulphur Spring	......	....	....	....	
Minnehaha Spring..................	......	....	....	....	
Monroe Spring	......	....	....	....	
Old Red Spring....................	1	60	....	Saline carbonated	Used commercially.
Pavilion Spring...................	1	12,000	50	....do	Not used commercially at present.
Putnam Springs....................	2	24	40	....do	Used commercially.
Saratoga A (or alum) Spring.......	......	....	....	....	
Saratoga Seltzer Spring...........	1	....	50	Saline carbonated.	Not used commercially at present.

Mineral springs of New York—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Saratoga spings—Continued.			°		
Star Spring (formerly Walton or Iodine Spring).	1	80	50	Saline, carbonated.	Used commercially.
Triton Spring (Kissingen)					Do.
Union Spring	1	12	48	Saline, carbonated	Do.
United States Spring					
Vichy Spring	1	240	50	Alkaline, saline, carbonated.	Do.
Walton Spring (same as Star)					
Washington Spring			45	Carbonated saline.	Do.
White Sulphur Springs	2	2,400+	48		Used for bathing.
Seneca Spa or Deer Lick Springs, 4 miles east of Buffalo, Erie County.				Sulphureted	
Sharon Springs, Sharon Springs, Schoharie County.	5	7,680+	48	Alkaline and saline, sulphureted.	Used commercially and as a resort.
Shee's Spa, McDonough Township, Chenango County.				Sulphureted	
Slaterville Magnetic Springs, Slaterville, Tompkins County.	27	2,700 ?	47		Do.
Spencer Springs, Spencer, Tioga Co					
Sulphur springs:					
At Wendell's Hollow, near Albany, Albany County.					
At Coeymans, Albany County					
At Guilderland, Albany County					
Four miles west of Rensselaerville, Albany County.					
Two miles west of Auburn, Cayuga County.					Unimproved.
One and one-half miles north of Auburn, Cayuga County.					Do.
Two miles north of Union Springs, Cayuga County.	2				
Near Randolph, Cattaraugus Co					
Near Van Buren Harbor, Chautauqua County.					
Near Fredonia, Chautauqua Co					
Near Sheridan, Chautauqua Co					
Near Laona, Chautauqua County					Do.
Two miles from Norwich, Chenango County.					
Near Pharsalia, Chenango County					
Near Beekmantown, Clinton Co					
Near Kinderhook, Columbia Co					Do.
Near Millers, in Claverack Township, Columbia County.					Unimportant
At Oakhill, near Catskill, Columbia County.					Unimproved.
At Preble, Cortland County					
Three miles from Chehocton, Delaware County.					
Near Amenia, Dutchess County					Do.
At Grand Island, Erie County					
In Amherst Township, Erie County					
Clarence Township, Erie County					
One and one-half miles west of Durham, Greene County.					Do.
One mile from Catskill, Greene Co					Do.
Three-fourths mile west of Athens, Greene County.					
Four miles west of Athens, Greene County.					
Near Richfield Springs, Warren Township, Herkimer County.	6				Used locally.
Near Starkville, Herkimer Co					
Near Winfield, Herkimer Co					
In Danube Township, Herkimer Co.					
At Mohawk, Herkimer County					
Near Newville, Herkimer County					
Near Martinsburgh, Lewis County					
At Caledonia, Livingston County					

Mineral springs of New York—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Sulphur springs—Continued.			°		
One-half mile south of Spencerport, Monroe County.					
In Gates Township, Monroe County					
In Mendon Township, Monroe Co.					
At Ogden, Monroe County					
In Deep Hollow Valley, northwestern part of Rochester, Monroe Co.					Used locally.
In Niagara County, two miles from Tonawanda.					
Near Niagara Falls, Niagara Co.					
Above Lewiston, Niagara County					
North part of Pendleton Township, Niagara County.					
In Augusta, Oneida County					
Near Vernon, Oneida County					
Near Paris, Oneida County.					
West of Elbridge, Onondaga Co.					
South of Manlius Village, Onondaga County.					
In Caruthers (?) Twp., Onondaga Co.					
Near Syracuse, Onondaga County					
Near Split Rock, Onondaga County					
Lake Sodom, near Manlius Centre, Onondaga County.					
In La Fayette Twp., Onondaga Co.					Used locally for medicinal purposes.
At outlet of Canandaigua Lake, Ontario County.					
Two and one-half miles from Newburgh, Orange County.					
In New Windsor Twp., Orange Co.					
In Holley, Orleans County	2				Weak and unimportant.
North end of Troy, Rensselaer Co.					
Near Bath, Rensselaer County					
Near Waterloo, Seneca County					
Near Campbell, Steuben County	1				Unimportant.
At Jasper, Steuben County	10				
Near Hammondsport, Steuben Co.					
Two and one-half miles southwest of Sag Harbor, Suffolk County.					
At Tioga Centre, Tioga County					
West of Springtown, Ulster County					
Two miles southeast of Ithaca, Tompkins County.					
Near Newark, Wayne County					Do.
Near Palmyra, Wayne County					Do.
In Sodus Township, Wayne Co					
At Clyde, Wayne County	3				Do.
Near Marion, Wayne County	4				Only one spring utilized.
Sulphur well, Peterson's farm, northwest of Rochester, Monroe County.					Unimproved.
Sulphuric acid springs:					
North part of Alabama Township, Genesee County.					
In Elba Township, Genesee Co					
Near South Byron, Genesee Co.					
Union Springs, Union Springs, Cayuga County.	2	10		Sulphureted and chalybeate.	Do.
Vallonia Springs, Vallonia Springs, Broome County.					
Verona Mineral Springs, near Verona, Oneida County.	4	160+	48	Saline	Used to some extent commercially and as a resort.
Victor Spring, Darien Centre, Genesee County.	1	40		Acid saline	Used commercially.
Yates Sulphur Springs, 1 mile south of Chittenango, Madison County.					
Yellow Spring, Southampton (Long Island), Suffolk County.				Chalybeate	Unimportant.

Analyses of mineral springs in New York.

Constituents.	Adirondack Spring.	Albany Artesian Well.		Auburn Spring, West Auburn.
Solids.	*Grains per gall.*[a]	*Grains per gall.*[b]	*Grains per gall.*[c]	*Grains per gall.*[d]
Sodium carbonate	5.14	40.00	40.00	....
Potassium carbonate	5.32	....	....	....
Calcium carbonate	18.54	32.00	32.00	....
Magnesium carbonate	16.62	16.00	12.00	....
Lithium carbonate	0.02	....	....	....
Manganese carbonate	Trace	....	....	....
Iron carbonate	5.04	[e]8.00	8.00	....
Calcium sulphate	11.13	....	....	120.00
Magnesium sulphate	....	....	....	25.60
Sodium chloride	14.34	504.00	472.00	6.00
Calcium chloride	....	....	4.00	....
Magnesium chloride	....	....	....	2.00
Alumina	Trace	....	....	....
Silica	0.74	....	....	....
Total	76.89	600.00	568.00	153.60
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen	....	....	....	12.00
Carbonic acid	67.27	184.00	....	....
Total	67.27	184.00	208.00	12.00

Constituents.	Avon Sulphur Springs.			
	Upper Spring.[f]	Lower Spring.	New Bath Spring.	Congress Hall Spring.
Solids.	*Grains per gall.*[g]	*Grains per gall.*[d]	*Grains per gall.*[c]	*Grains per gall.*[h]
Calcium carbonate	8.00	29.33	26.96	9.25
Sodium sulphate	16.00	13.73	38.72	21.02
Calcium sulphate	84.00	57.44	3.52	27.61
Magnesium sulphate	10.00	49.61	8.08	19.07
Sodium chloride	18.40	....	5.68	29.11
Calcium chloride	....	8.41	....	....
Sodium iodide	....	Trace[i]	....	....
Sodium sulphide	....	....	....	99.55
Calcium sulphide	....	....	....	
Magnesium sulphide	....	....	....	
Total	136.40	158.52	82.96	205.61
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen	12.00	10.02	31.28	27.63
Carbonic acid	5.60	3.92	....	22.04
Oxygen	....	0.56	....	0.97
Nitrogen	....	5.42	....	3.88
Total	17.60	19.92	....	54.52

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[a] C. Collier, analyst.
[b] Wm. Meade, analyst (1827).
[c] L. C. Beck, analyst (1842).
[d] J. R. Chilton, analyst.
[e] With silica.
[f] Same as Middle Spring of Beck's report
[g] J. Hadley, analyst.
[h] H. M. Baker, analyst (1874).
[i] Contains iodine and bromine.

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Analyses of mineral springs in New York—Continued.

Constituents.	Ballston Spa Springs.				
	Sans Souci Spring.	Artesian Lithia Spring.	Franklin Artesian Well.	United States.	Washington Lithia well. (Old Conde Dentonian.)
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate	12.66			16.88	
Sodium bicarbonate		11.93	94.60		34.40
Calcium carbonate	43.41			[f]29.20	
Calcium bicarbonate		238.16	202.33		178.48
Magnesium carbonate				5.76	
Magnesium bicarbonate	39.10	180.60	177.87		158.85
Strontium bicarbonate		0.87	Trace		0.19
Lithium bicarbonate		7.75	6.78		15.51
Iron carbonate	5.95				
Iron bicarbonate		1.58	1.61		2.30
Barium bicarbonate		3.88	1.23		4.74
Sodium sulphate				1.76	
Potassium sulphate		0.52	0.76		
Sodium phosphate		0.05	0.01		Trace
Sodium biborate		Trace	Trace		Trace
Sodium chloride	143.73	750.03	659.84	424.96	645.48
Patassium chloride		33.28	38.93		9.28
Sodium bromide		3.64	4.67		2.37
Calcium fluoride		Trace	Trace		Trace
Sodium iodide	1.30	0.12	0.24		0.22
Alumina		0.08	0.26		0.40
Silica	1.00	0.76	0.74	8.00	1.03
Organic matter		Trace	Trace		Trace
Total	247.15	1,233.25	1,184.37	486.56	1,047.70
Gases.					
Carbonic acid		426.114	460.066	244.00	358.345

Constituents.	Chittenango Springs.			Clifton Springs: Sulphur Spring.	Columbia White Sulphur Springs.
	White Sulphur Spring.	Cave Spring.	Magnesia Spring.		
Solids.	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[g]	*Grains per gallon.*[h]
Calcium carbonate				9.68	21.79
Magnesium carbonate				13.12	
Magnesium bicarbonate	22.02	23.97			
Iron carbonate			20.78		
Iron bicarbonate	0.08	0.16	0.32		
Sodium hyposulphite		0.26	0.02		3.15
Sodium sulphate	0.21			7.76	
Calcium sulphate	81.42	106.12	115.09	69.20	64.94
Strontium sulphate	Trace	Trace	Trace		
Magnesium sulphate	1.95	7.59	12.72	16.48	
Sodium phosphate					2.14
Sodium chloride	1.04	1.57	1.83	9.28	84.72
Calcium chloride				4.08	
Potassium chloride	0.16	0.23	0.33		1.19
Magnesium chloride				4.08	31.43
Lithium chloride	Trace	Trace	Trace		
Iron sesquichloride					3.42
Sodium sulphide	0.12	0.39	0.75		
Calcium sulphide		1.12	0.93		
Alumina	0.08	0.22	Trace		
Silica	0.28	0.52	0.58		
Sulphur	Trace				
Loss					0.82
Organic matter				Trace	
Total	107.36	142.15	153.35	133.68	218.60
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen	0.884	2.754	5.623	Present	4.491
Carbonic acid	20.480	15.934	19.436	Present	

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[a] John H. Steele, analyst (1830).

[b] C. F. Chandler, analyst (1868).

[c] C. F. Chandler, analyst.

[d] L. C. Beck, analyst.

[e] C. F. Chandler, analyst (1869).

[f] With iron oxide.

[g] J. R. Chilton, analyst (1852).

[h] Atwood, analyst.

Analyses of mineral springs in New York—Continued.

Constituents.	Barton Sulphur Springs.	Cherry Valley Springs.		
		Bath-House Spring.	Spring north of bath-house.	Phosphate Spring.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[c]
Sodium carbonate	11.12			
Calcium carbonate	3.65	9.41	14.75	2.87
Magnesium carbonate	1.99	17.82	9.96	4.58
Iron carbonate			2.45	0.62
Ammonium carbonate	6.95			
Sodium sulphate		11.08		
Calcium sulphate	0.20	57.68	149.46	5.27
Magnesium sulphate		24.56		
Calcium phosphate				13.77
Sodium chloride	2.05	12.44	2.13	0.47
Calcium chloride		2.80		
Potassium chloride	0.11		2.49	
Magnesium chloride		3.68		
Calcium sulphide		0.60		
Iron oxide	0.36	0.36		
Alumina				
Silica	1.16		3.64	0.62
Sulphur	1.52			
Organic matter		0.28		
Carbonic acid	2.62			
Total	31.73	140.71	184.88	28.20
Gases.				
Oxygen	0.20			

Constituents.	Cherry Valley Springs.	Yates Sulphur Springs.	Doxtatter's, or Longmuir's Well, Rochester.	Verona Mineral Springs.
	Phosphate Spring.			
Solids.	*Grains per gallon.*[d]	*Grains per gallon.*[e]	*Grains per gallon.*[e]	*Grains per imp. gall.*[f]
Calcium carbonate		7.04	[g]11.84	38.47
Magnesium bicarbonate	17.27			
Manganese bicarbonate	0.01			
Iron bicarbonate	0.20			
Sodium sulphate	0.04	18.28	55.92	
Calcium sulphate	41.13	102.00		63.19
Magnesium sulphate	0.47			
Potassium sulphate	0.46			
Strontium sulphate	Trace			
Lithium sulphate	0.02			
Barium sulphate	0.01			
Calcium phosphate (acid)	0.60			
Sodium biborate	Trace			
Sodium nitrate	Trace			
Sodium chloride	0.68	1.12		562.89
Calcium chloride			52.16	82.61
Potassium chloride				4.06
Magnesium chloride				27.11
Lithium chloride				2.37
Sodium bromide	Trace			
Alumina	0.14			
Silica	0.29			0.59
Organic matter	Trace	Trace		
Total	61.32	123.44	119.92	781.29
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen			17.28	
Carbonic acid			Trace	

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[a] F. F. Thomas, analyst.

[b] J. R. Chilton, analyst.

[c] Perkins, analyst.

[d] C. F. Chandler, analyst (1876).

[e] L. C. Beck, analyst (1842).

[f] Peter Collier, analyst (1870).

[g] With magnesium carbonate and iron oxide.

Analyses of mineral springs in New York—Continued.

Constituents.	Crystal Springs.	Deep Rock Mineral Spring.	Florida Spring.	Halleck's Spring.
	Parts in 100.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]
Sodium bicarbonate			22.14	
Calcium carbonate		18.19		
Calcium bicarbonate			8.32	
Magnesium bicarbonate			6.97	
Sodium hyposulphate			0.71	
Calcium sulphate				40.00
Potassium sulphate			1.89	
Sodium chloride		308.18	5.88	624.00
Calcium chloride				104.00
Potassium chloride		149.08		
Magnesium chloride		10.25		32.00
Iron sulphide			0.18	
Sodium sulphide			2.01	
Magnesia	.008			
Lime	.008			
Iron oxide	.001	Trace		
Alumina	Trace		Trace	
Silica	Trace	71.70	0.79	
Soda	.001			
Chlorine	.003			
Iodine and phosphoric acid	Trace			
Carbonic acid (combined)	.012			
Sulphuric acid	.001	Trace		
Loss		1.78		
Total	0.029	559.18	48.39	800.00
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbureted hydrogen				Trace
Sulphureted hydrogen	Trace		8.765	
Carbonic acid	Trace	Undetermined	32.169	Trace

Constituents.	Lebanon Thermal Spring.	Nunda Mineral Springs.	Chlorine Spring.	Excelsior Spring.	Lockport Mineral Spring.
	Grains per gallon.[e]	*Grains per gallon.*[f]	*Grains per gallon.*[g]	*Grains per gallon.*[g]	*Grains per gallon.*[h]
Sodium carbonate	2.41				
Calcium carbonate	4.04	104.10	22.38	15.24	9.27
Iron carbonate		1.05			
Calcium sulphate		184.41	38.68	36.45	5.72
Potassium sulphate	1.04				
Magnesium sulphate	1.06	203.58			
Sodium chloride	0.96	6.82	646.42	584.53	111.42
Sodium sulphide	0.02				
Iron oxide	0.94		Present		0.05
Alumina	0.45	Trace		1.02	
Silica	3.25	000.12	0.29		0.90
Organic matter	10.21				Trace
Magnesium carbonate					3.21
Sodium sulphate			26.28	13.16	
Calcium chloride					45.08
Potassium chloride					3.52
Magnesium chloride			17.86	17.69	11.04
Magnesium bromide				0.15	
Sodium bromide					1.57
Sodium iodide					2.36
Free carbonic acid			Present	Present	
Total	24.38	500.08	751.86	668.24	194.14
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen					2.86
Carbonic acid	0.48				5.79
Oxygen	2.00				
Nitrogen	3.52				

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[a] J. Fowler, analyst (1880).
[b] S. H. Douglas, analyst (1871).
[c] C. F. Chandler, analyst (1870).
[d] J. Noyes, analyst.
[e] H. Dussance, analyst.
[f] S. A. Lattimore, analyst (1878).
[g] Charles A. Goessman, analyst (1868).
[h] J. Hadley, analyst (1861).

Analyses of mineral springs in New York—Continued.

Constituents.	Sharon Springs.				
	White Sulphur Spring.	Magnesia Spring.	Red Sulphur Spring.	Gardner Magnesia Spring.	Eye-Water Spring.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[a]
Sodium bicarbonate			0.49	0.54	
Calcium bicarbonate			12.93	9.70	
Magnesium bicarbonate	24.00	30.50	0.69	1.36	32.00
Calcium sulphate	85.40	76.00	96.64	93.50	77.50
Magnesium sulphate	34.00	22.70	18.96	19.68	7.50
Sodium chloride	2.70	3.00	0.33	1.23	2.50
Magnesium chloride			0.73	0.44	
Calcium chloride			0.07	0.16	
Calcium sulphide	3.00	0.50	0.89	0.63	
Magnesium sulphide					
Silica			0.45	0.40	
Total	149.10	132.70	132.18	127.64	119.50
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen	20.50	3.30	10.50	6.00	
Carbonic acid			4.58	2.22	
Atmospheric air			4.00	3.00	

Constituents.	Sharon Springs.			
	Chalybeate Spring.	Gardner Magnesia Spring.	Red Sulphur Spring.	White Sulphur Spring.
Solids.	*Grains per gallon.*[d]	*Grains per gallon.*[e]	*Grains per gallon.*[e]	*Grains per gallon.*[f]
Sodium carbonate		0.34	0.34	
Calcium carbonate		6.73	8.97	
Magnesium carbonate	8.96	0.80	0.41	
Sodium sulphate	3.74			
Calcium sulphate	63.80	93.50	96.64	55.84
Potassium sulphate	Trace			
Magnesium sulphate	8.15	19.68	18.96	21.20
Iron protosulphate	1.40			
Sodium chloride		1.23	0.33	1.12
Calcium chloride		0.16	0.06	
Magnesium chloride		0.43	0.73	1.20
Sodium sulphide				[g]1.12
Calcium sulphide		6.25	0.89	
Magnesium sulphide				
Silica		0.40	0.45	
Organic matter	28.48			
Total	114.53	129.52	127.78	80.48
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen		6.00	10.48	8.00
Carbonic acid		2.21	4.56	
Atmospheric air		3.00	4.00	
Total		11.21	19.04	8.00

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[a] Lawrence Reid, analyst (1845).
[b] J. G. Pohle, analyst.
[c] J. G. Pohle, analyst (1865).
[d] Maische, analyst (1861).
[e] Lawrence Reid, analyst.
[f] J. R. Chilton, analyst.
[g] With extractive matter.

Analyses of mineral springs in New York—Continued.

Constituents.	Oak Orchard Acid Springs.					
	Spring No. 1.		Spring No. 2.	Oak Orchard Acid Water.		
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Parts in 1,000.*[e]	*Parts in 1,000.*[f]
Sodium sulphate	6.34			3.16	0.12	0.09
Calcium sulphate	74.89	39.60	12.41	13.72	1.11	1.12
Potassium sulphate	5.52			2.48	0.11	0.08
Aluminium sulphate	21.69	9.68		6.41	0.37	0.32
Magnesium sulphate	35.60	8.28	4.98	8.49	0.46	0.53
Iron sulphate			39.23		0.43	0.42
Iron protosulphate	28.62	14.32		32.22		
Sodium chloride	2.44			1.43		0.04
Silica	4.59	1.04	1.84	3.33	0.06	0.07
Chlorine					Trace	
Organic matter		3.28	10.88	6.65	Trace	
Sulphuric acid	134.73	82.96	129.06	133.31	2.01	2.01
Total	314.42	159.16	198.40	211.20	4.67	4.68

Constituents.	Massena or St. Regis Springs.	Messena Sulphur Springs.	Richfield Springs.				
			Name of spring unknown.	Sulphur Spring.	White Sulphur Spring.	Iron Spring.	Magnesia Spring.
Solids.	*Grains per gall.*[g]	*Grains per gall.*[h]	*Grains per gall.*[i]	*Grains per gall.*[j]	*Grains per gall.*[k]	*Grains per gall.*[i]	*Grains per gall.*[i]
Calcium carbonate		14.80	6.96				
Calcium bicarbonate	4.85			24.47		11.71	16.11
Magnesium carbonate			11.84				
Magnesium bicarbonate				6.01	31.74	12.52	3.97
Iron bicarbonate	0.49			0.24	Trace	4.92	0.13
Sodium hyposulphate	4.21						
Sodium sulphate	0.50			22.29		0.30	12.79
Sodium hydrosulphate					0.88		
Calcium sulphate	60.03	68.40	20.00	67.39	112.84	5.00	38.63
Potassium sulphate					1.67		
Strontium sulphate					0.01		
Magnesium sulphate		10.88	30.00	32.82	5.15		18.81
Barium sulphate					Trace		
Sodium phosphate	1.32						
Calcium phosphate					Trace		
Sodium chloride	76.79		[l]1.49	21.73	0.52	0.43	10.20
Calcium chloride		10.64					
Potassium chloride	0.51			8.23			4.51
Magnesium chloride	29.93						
Lithium chloride					0.02		
Magnesium bromide	0.67						
Sodium sulphide	1.40				1.72		
Sodium and calcium sulphides				6.22			0.06
Calcium sulphide					0.09		
Calcium and magnesium sulphides.			2.00				
Alumina				0.10	Trace		
Silica				1.85	0.64	0.81	1.17
Organic matter	[m]11.18		[n]153.50				
Total	191.88	104.72	225.79	190.85	154.28	35.69	106.38
Gases.	*Cub. in.*	*Cub. in.*	*Cub. in.*	*Cub. in.*	*Cub. in.*	*Cub. in.*	*Cub. in.*
Sulphureted hydrogen	5.307		24.24	3.6288	14.206		0.3160
Carbonic acid				2.9412		15.9236	2.2032

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[a] Silliman & Norton, analysts.

[b] J. R. Chilton, analyst.

[c] E. Emmons, analyst.

[d] Porter, analyst.

[e] H. Erni, analyst (1850).

[f] W. J. Craw, analyst (1850).

[g] Ford F. Mayer, analyst.

[h] L. C. Beck, analyst.

[i] Lawrence Reid, analyst.

[j] Theo. Deecke, analyst.

[k] C. F. Chandler, analyst.

[l] With magnesium chloride.

[m] With silicate of soda.

[n] Undetermined matter.

Analyses of mineral springs in New York—Continued.

Constituents.	Saratoga Springs.				
	Champion Spouting Spring.	Columbian Springs.	Crystal Springs.	Congress Spring.	
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate					16.00
Sodium bicarbonate	17.62	15.40	10.06	8.98	
Calcium carbonate		68.00		98.10	144.00
Calcium bicarbonate	227.07		101.88		
Magnesium bicarbonate	193.91	46.71	75.16	95.79	32.00
Strontium bicarbonate	0.08		Trace		
Lithium bicarbonate	6.25		4.33		
Iron carbonate		5.58		5.07	
Iron bicarbonate	0.65		2.04		
Barium bicarbonate	2.08		0.73		
Potassium sulphate	0.25		2.16		
Sodium phosphate	0.01		Trace		
Sodium biborate	Trace		Trace		
Sodium chloride	702.24	267.00	328.47	385.00	434.40
Potassium chloride	40.45		8.33		
Potassium bromide		Trace		Trace	
Sodium bromide	3.58		0.41		
Calcium fluoride	Trace		Trace		
Sodium iodide	0.23	2.56	0.06	3.50	
Alumina	0.46		0.31		
Silica	0.70	2.05	3.21	1.50	[f]Trace
Organic matter	Trace		Trace		
Total	1,195.58	407.80	537.15	597.94	626.40
Gases.					
Atmospheric air		4.50		7.00	
Azote					7.20
Carbonic acid	465.46	272.06	317.45	311.00	312.80

Constituents.	Saratoga Springs.				
	Congress Spring.			Empire Spring.	
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[g]	*Grains per gallon.*[h]	*Grains per gallon.*[c]	*Grains per gallon.*[i]
Sodium carbonate		0.56	7.20		
Sodium bicarbonate	10.77			9.02	30.85
Calcium carbonate		116.00	86.14		
Calcium bicarbonate	143.40			109.66	141.82
Magnesium carbonate		56.80	78.62		
Magnesium bicarbonate	121.76			42.96	41.98
Strontium bicarbonate	Trace			Trace	
Lithium bicarbonate	4.76			2.08	
Iron carbonate			0.84		
Iron bicarbonate	0.34			0.79	Trace
Barium bicarbonate	0.98			0.07	
Sodium sulphate			0.65		
Potassium sulphate	0.89			2.77	
Sodium phosphate	0.02			0.02	
Sodium biborate	Trace			Trace	
Sodium chloride	400.44	385.44	363.83	506.63	269.70
Potassium chloride	8.05			4.29	
Potassium bromide		Trace	[j]5.92		
Sodium bromide	8.56			0.27	
Calcium fluoride	Trace			Trace	
Sodium iodide	0.14	4.02		Trace	[k]12.00
Iron oxide		0.64			
Alumina	Trace		0.32	0.42	
Silica	0.84		0.47	1.46	
Organic matter				Trace	
Total	700.90	563.46	543.99	680.44	496.35
Gases.					
Atmospheric air			5.41		
Carbonic acid	392.80		284.65	314.67	

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[a] C. F. Chandler, analyst (1871).
[b] John H. Steele, analyst (prior to 1838).
[c] C. F. Chandler, analyst.
[d] John H. Steele, analyst.
[e] J. D. Dana, analyst.
[f] With iron.
[g] Davy and Faraday, analysts, London.
[h] J. R. Chilton, analyst (1843).
[i] E. Emmons, analyst.
[j] With sodium iodide.
[k] Or iodine.

Analyses of mineral springs in New York—Continued.

Constituents.	Saratoga Springs.				
	Eureka Spring.	Excelsior Spring.	Flat Rock Spring.		Geyser Spouting Spring.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium bicarbonate	8.75	15.00	20.79	9.10	71.23
Calcium carbonate			60.57		
Calcium bicarbonate	41.32	77.00		98.63	168.39
Magnesium bicarbonate	29.34	32.33	42.70	29.47	149.34
Strontium bicarbonate				0.01	0.43
Lithium bicarbonate				3.23	9.00
Iron carbonate			5.39		
Iron bicarbonate	3.00	3.22		0.09	0.98
Barium bicarbonate				0.10	2.01
Sodium sulphate		1.32			
Potassium sulphate				0.48	0.32
Strontium sulphate		Trace			
Magnesium sulphate	2.15				
Sodium phosphate				0.04	Trace
Sodium biborate				Trace	Trace
Sodium chloride	166.81	370.64	148.87	108.85	562.08
Potassium chloride				7.99	24.64
Magnesium chloride				10.83	
Potassium bromide	1.57	Trace	Trace		
Sodium bromide				0.32	2.21
Calcium fluoride					Trace
Sodium iodide	4.67	4.24	1.33	0.01	0.25
Alumina	0.28		Trace	0.04	Trace
Silica	0.53		Trace	1.34	0.66
Organic matter				Trace	Trace
Sodium silicate		4.00			
Potassium silicate		7.00			
Total	258.37	514.75	279.65	270.53	991.54
Gases.					
Atmospheric air			6.50		
Carbonic acid	239.00	250.00	287.50		454.08

Constituents.	Saratoga Springs.				
	Hamilton Spring.		Hathorn Spring.	High Rock Springs.	
Solids.	*Grains per gallon.*[f]	*Grains per gallon.*[a]	*Grains per gallon.*[g]	*Grains per gallon.*[g]	*Grains per gallon.*[f]
Sodium carbonate		34.25			
Sodium bicarbonate	27.04		4.29	34.89	17.54
Calcium carbonate	92.40	97.99			69.29
Calcium bicarbonate			170.65	131.74	
Magnesium carbonate		39.06			
Magnesium bicarbonate	85.20		176.46	54.92	61.59
Strontium bicarbonate			Trace	Trace	
Lithium bicarbonate			11.45		
Iron carbonate		4.62			5.58
Iron bicarbonate	5.39		1.13	1.48	
Barium bicarbonate			1.74	Trace	
Potassium sulphate				1.61	
Sodium phosphate			Trace		
Calcium phosphate				Trace	
Sodium biborate			Trace		
Sodium chloride	297.30	298.66	509.97	390.13	189.10
Potassium chloride			9.60	8.50	
Potassium bromide	Trace				Trace
Sodium bromide			1.53	0.73	
Calcium fluoride			Trace	Trace	
Sodium iodide	3.00	3.59	0.19	0.08	2.50
Alumina			0.13	1.22	Trace
Silica		1.00	1.26	2.26	Trace
Organic matter			Trace	Trace	
Total	460.33	479.17	888.40	627.56	345.60
Gases.					
Atmospheric air	4.00				5.00
Carbonic acid	316.00	320.00	375.75	409.46	304.00

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[a] Allen, analyst.
[b] Allen, analyst (1879).
[c] John H. Steele, analyst.
[d] C. F. Chandler, analyst (1885).
[e] C. F. Chandler, analyst (1870).
[f] John H. Steele, analyst (prior to 1838).
[g] C. F. Chandler, analyst.

Analyses of mineral springs in New York—Continued.

Constituents.	Saratoga Springs.			
	Kissingen or Triton Spring	Pavilion Spring.		Putnam Spring.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[c]
Sodium carbonate			4.92	
Sodium bicarbonate	67.62	3.76		14.32
Calcium carbonate			52.84	
Calcium bicarbonate	140.26	120.17		68.80
Magnesium carbonate			56.92	
Magnesium bicarbonate	70.47	76.27		51.60
Strontium bicarbonate	Trace	Trace		
Lithium bicarbonate	5.13	9.49		
Iron carbonate			8.51	
Iron bicarbonate	1.56	2.57		7.00
Barium bicarbonate	0.99	0.88		
Sodium sulphate			1.48	1.68
Potassium sulphate	Trace	2.03		
Sodium phosphate		Trace		0.21
Calcium phosphate			0.19	
Sodium biborate		Trace		
Sodium chloride	338.50	459.90	187.68	214.00
Potassium chloride	16.98	7.66		
Potassium bromide			[d]2.59	Trace
Sodium bromide	1.80	0.99		
Calcium fluoride	Trace	Trace		
Sodium iodide	0.04	0.07		2.00
Alumina	Trace	0.33	0.42	0.56
Silica	1.28	3.16	1.16	0.84
Organic matter		Trace		
Total	644.63	687.28	311.71	361.01
Gases.				
Carbonic acid	361.50	332.46	359.50	326.40
Atmospheric air			5.30	6.40

Constituents.	Saratoga Springs.			
	New Putnam Spring.	Red Spring.	Saratoga A or Alum Spring.	Seltzer Spring.
Solids.	*Grains per gallon.*[b]	*Grains per gallon.*[e]	*Grains per gallon.*[f]	*Grains per gallon.*[g]
Sodium bicarbonate	8.08	15.33	6.75	29.43
Calcium bicarbonate	157.56	101.26	56.85	89.87
Magnesium bicarbonate	173.61	42.41	20.48	40.84
Strontium bicarbonate	0.11	Trace		Trace
Lithium bicarbonate	9.83	0.94	1.72	0.90
Iron bicarbonate	0.45		1.72	1.70
Barium bicarbonate	0.38			Trace
Sodium sulphate			2.50	
Calcium sulphate			0.45	
Potassium sulphate	2.26		0.87	0.56
Magnesium sulphate			0.29	
Sodium phosphate	Trace			Trace
Calcium phosphate				Trace
Sodium biborate	Trace			Trace
Sodium chloride	268.04	83.53	565.30	184.29
Calcium chloride			Trace	
Potassium chloride	14.87	6.86	0.36	1.34
Magnesium chloride			Trace	
Sodium bromide	1.62			0.68
Calcium fluoride	Trace			Trace
Sodium iodide	Trace			0.03
Boracic acid				Trace
Iron oxide		[h]2.10		
Alumina	0.22		0.38	0.37
Silica	3.00	3.25	1.46	2.56
Organic matter	Trace		Trace	Trace
Total	640.03	255.68	658.63	302.02
Gases.				
Carbonic acid			212.00	324.08

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[a] Sharples, analyst (1872).

[b] C. F. Chandler, analyst (1882).

[c] J. R. Chilton, analyst (1840).

[d] With sodium iodide.

[e] Appleton, analyst.

[f] J. G. Pohle, analyst.

[g] C. F. Chandler, analyst (1869).

[h] With traces of phosphates.

Analyses of mineral springs in New York—Continued.

Constituents.	Saratoga Springs.			
	Star Spring.	Union Spring.		United States Spring.
Solids.	*Grs. per gall.*[a]	*Grs. per gall.*[b]	*Grs. per gall.*[c]	*Grs. per gall.*[a]
Sodium carbonate		12.80		
Sodium bicarbonate	12.66		17.01	4.67
Calcium carbonate		41.60		
Calcium bicarbonate	124.46		96.70	93.12
Magnesium carbonate		84.27		
Magnesium bicarbonate	61.91		109.69	72.88
Strontium bicarbonate	Trace		Trace	0.02
Lithium bicarbonate	1.59		2.61	4.85
Iron carbonate		5.45		
Iron bicarbonate	1.21		0.27	0.71
Barium bicarbonate	0.10		1.70	0.91
Potassium sulphate	5.40		1.82	
Sodium phosphate	Trace		0.03	0.02
Sodium biborate	Trace		Trace	Trace
Sodium chloride	398.36	243.62	453.30	141.87
Potassium chloride	9.70		8.73	8.62
Potassium bromide		Trace		
Sodium bromide	0.57		1.30	0.84
Calcium fluoride	Trace		Trace	Trace
Sodium iodide	0.18	3.60	0.04	0.05
Alumina	Trace	1.57	0.82	0.09
Silica	1.28		2.65	3.19
Organic matter	Trace		Trace	Trace
Total	617.37	392.91	696.17	331.84
Gases.				
Carbonic acid	407.65	344.16	384.97	245.73
Atmospheric air		4.62		

Constituents.	Saratoga Springs.			
	Vichy Spring.	Walton or Iodine Spring (Star Spring).	Washington Spring.	
Solids.	*Grs. per gall.*[a]	*Grs. per gall.*[d]	*Grs. per gall.*[e]	*Grs. per gall.*[f]
Sodium carbonate		2.00		
Sodium bicarbonate	82.87		8.48	16.50
Calcium carbonate		26.00		92.60
Calcium bicarbonate	95.52		84.10	
Magnesium carbonate		75.00		
Magnesium bicarbonate	41.50		65.97	40.92
Strontium bicarbonate	Trace			
Lithium bicarbonate	1.76			
Iron carbonate		1.00		3.25
Iron bicarbonate	0.05		3.80	
Barium bicarbonate	0.59			
Potassium sulphate	Trace			
Magnesium sulphate			0.05	
Sodium phosphate	Trace			
Sodium biborate	Trace			
Sodium chloride	128.69	187.00	182.73	281.50
Calcium chloride			0.20	
Potassium chloride	14.11			
Magnesium chloride			0.68	
Potassium bromide			0.47	
Sodium bromide	0.99			
Calcium fluoride	Trace			
Sodium iodide	Trace	3.50	2.24	2.75
Alumina	0.48		Trace	
Silica	0.76		1.50	1.50
Organic matter	Trace			
Total	367.32	294.50	350.22	439.02
Gases.				
Carbonic acid	383.07	326.00	363.77	262.50
Atmospheric air		4.00		6.80

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[a] C. F. Chandler, analyst.

[b] J. R. Chilton, analyst (1841).

[c] C. F. Chandler, analyst (1873).

[d] E. Emmons, analyst (1839).

[e] J. R. Chilton, analyst.

[f] John H. Steele, analyst (prior to 1838).

NEW JERSEY.

This State is not conspicuous for the number of her mineral springs. Schooley's Mountain Spring is the only well-known resort.

The water of a spring at Woodbridge, in Middlesex County, was at one time bottled for sale, but so far as reported none of the waters of the State is on sale at present. Unimproved weak chalybeate springs doubtless exist in many portions of the State, but they are at present of comparatively little importance.

A number of artesian wells have been sunk at Newark, Paterson, Jersey City, and in other parts of the State, and the water in many of them is quite highly mineralized. Several of the analyses are included in the table. So far as known, they are not utilized medicinally.

Mineral springs of New Jersey.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Artesian wells:[a]			°		
At Passaic Rolling Mill, Paterson, Passaic County.	......	....	......	....	Saline.
At Celluloid Works, Newark, Essex County.	......	....	......	....	Calcic, saline.
On Passaic River (Lister Brothers), Newark, Essex County.	......	....	55½	....	Do.
At Limbech & Betz's, Ninth street, Jersey City, Hudson County.	......	....	52½	....	Saline.
At Winslow, Camden County	......	....	......	....	Alkaline.
Bishop's Well (45 feet), New Brunswick, Middlesex County.	......	....	......	Calcic	
Manasquan Spring, Point Pleasant, Ocean County.	......	....	......	....	
Mineral springs:					
At Oceanville, (?) Monmouth Co.	......	....	......	....	
On Pohatcong Mountain, near Broadway, Warren County.	......	....	......	....	
Paint Spring, Kittatinny Mountain, Warren County, near Delaware Gap Water.	......	....	......	....	
Schooley's Mountain Spring, Schooley's Mountain, Morris County.	1	20	58	Chalybeate ...	Resort.
Spa Spring, Woodbridge, Middlesex County.	1	....	Cold	Chalybeate ...	Unimproved, but was once bottled and sold.
Warwick Spring, Newark, Essex Co	......	....	......	Saline........	

[a] Only those of which analyses are given in the table are included here.

Analyses of mineral springs in New Jersey.

Constituents.	Schooley's Mountain Spring.	Warwick Spring.	Artesian Wells.	
			Passaic Rolling Mill.	Lister Bros., Newark.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]
Sodium carbonate	0.58			
Sodium bicarbonate		11.27		
Magnesium carbonate	1.60			1.55
Magnesium bicarbonate		18.09		
Iron carbonate	0.58			
Iron bicarbonate		2.72		
Manganese carbonate	Trace			
Calcium carbonate	1.42			
Calcium bicarbonate		41.82		
Ammonium bicarbonate		18.43		
Calcium sulphate	1.68		120.70	106.98
Sodium sulphate				15.94
Magnesium sulphate				25.87
Alumina	0.14	0.70		
Ammonia	Trace			
Silicic acid	0.74	0.82		
Sodium chloride	0.43	13.41	408.46	2.47
Potassium chloride		5.40	5.54	
Calcium chloride			278.32	
Magnesium chloride			109.44	
Iron and aluminium chlorides			7.00	
Sodium bromide		Trace		
Sodium phosphate		0.09		
Potassium nitrate		Trace		
Organic matter		Trace		
Bromide			Trace	
Iodine			Trace	
Total	7.17	112.75	929.46	152.81
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	Undetermined	101.03	Undetermined	Undetermined

Constituents.	Artesian Wells.			Bishop's Well, New Brunswick.
	Celluloid Works, Newark.	Limbech & Betz's, Jersey City.	Winslow.	
Solids.	*Grains per gallon.*[d]	*Grains per gallon.*[d]	*Parts in 1,000.*[d]	*Grains per gallon.*
Magnesium carbonate	6.10			
Magnesium sulphate				30.88
Calcium sulphate				148.62
Sodium sulphate	11.70			
Magnesium sulphate	18.70			
Calcium sulphate	85.10			
Silicic acid	2.00		.0140	
Potash			.0100	
Sodium chloride	0.60			10.00
Soda		39.50	.0554	
Lime		6.95	.0202	
Magnesia		9.36	.0079	
Sulphuric acid		4.11	.0027	
Chlorine		65.50	.0002	
Carbonic acid			.0520	
Iron peroxide			.0030	
Total	124.20	125.42	.1654	189.50

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[a] C. McIntyre, jr., analyst (1870).

[b] C. F. Chandler, analyst (1870).

[c] New Jersey State Geologist's Report, 1880.

[d] New Jersey State Geologist's Report, 1879.

PENNSYLVANIA.

Very little has ever been published with especial reference to Pennsylvania mineral waters. Walton's Mineral Springs of the United States and Canada (edition of 1883) credits the State with eight locations. In Moorman's book of 1873 thirteen are mentioned, while Pepper's list of 1880 contains thirty-two. In the present list forty-four are included, of which sixteen are places of resort and five are used commercially. Several of the springs have been popular resorts for years. Bedford Springs has been so utilized since 1804. Next to these the Gettysburg Springs are probably as well known as any other in the State. Cresson, Minnequa, and Blossburg Springs are also among the most important. The Bath Spring at Bristol, which was a place of considerable resort in Revolutionary times, has so declined in importance that few are aware even of its existence. Some of the springs, like those at Ephrata, Yellow Springs, and Caledonia Springs, are summer resorts, but the waters can scarcely be called mineral waters, as they are merely notable for their purity and the desirability of their situation.

The Reports of the Second Geological Survey present much information in relation to the mineral springs of Pennsylvania, and contain many analyses, made mostly by Dr. Genth. These have been drawn upon and form the majority of the analyses given in the table following the list of springs.

The chalybeate springs, as in most of the neighboring States, outnumber the others. There are a large number of sulphureted waters and one spring (Blossburg) is known to contain free sulphuric acid. The Perry County Spring is the only warm spring. In most of the books the temperature of this spring is given as from 70° to 72° Fahr., but information derived directly from the spring owner gives it as 66° Fahr.

Mineral springs of Pennsylvania.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks.
Adams White Sulphur Springs, 1 mile north of Chaneysville, Bedford Co.	......	......	......	Sulphureted	Once had considerable reputation as a resort.
Addison Ridge Chalybeate Springs, Monroe Township, Bedford County.	4	......	......	Chalybeate	
Alum Rock Spring, Alum Rock, Clarion County.	......	......	......	....do	
Bath Chalybeate Spring, Bristol, Bucks County.	1	......	......	....do	Was once a resort.
Bedford Springs, Bedford, Bedford County.	7	2,400	52.7 to 62.6	Saline, sulphureted, and chalybeate.	Used commercially and as a resort.
Black Barren Spring, Pleasant Grove, Lancaster County.	1	60	52	....	Do.
Blossburg Springs, Blossburg, Tioga County.	2+	......	......	Acid, chalybeate	Has considerable local reputation.
Caledonia or Sweeney's Springs, 15 miles from Chambersburg, Franklin Co.	......	......	......	....	Summer resort.
Carlisle White Sulphur Springs, near Carlisle, Cumberland County.	3	60	......	Mild sulphurous	Resort to limited extent.

Mineral springs of Pennsylvania—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Chalybeate springs:			°		
Four miles from Pittsburgh, Allegheny County.					
Two miles north of Chambersburg, Franklin County.			53		
Cresson Springs, Cresson Cambria Co.	8			Chalybeate, &c	Resort.
Doubling Gap White Sulphur Springs, Doubling Gap, near Newville, Cumberland County.	5			Sulphureted and chalybeate.	Do.
East Clarion Spring, Elk County				Saline	
Ephrata Spring, Ephrata, Lancaster Co.			57		Do.
Fayette Spring, Fayette Springs, Fayette County.	1		48	Chalybeate	Once a resort.
Frankfort Springs, Frankfort Springs, Beaver County.	9	200+	42–48	do	Resort.
Gettysburg Katalysine Spring, Gettysburg, Adams County.			57	Alkaline	Used commercially.
Gettysburg Lithia Spring, Gettysburg, Adams County.				do	Do.
Guylyck and Gaylord's Spring, Blossburg, Tioga County.	1	160		Acid chalybeate.	Do.
Hater's Chalybeate Spring, 1 mile northeast of Bedford, Bedford County.	1			Chalybeate	Resort.
Kane Geyser Well (2,000 feet), near Sargent, McKean County.				Saline	
Kane Sulphur Spring, 2½ miles northwest of Kane, McKean County.				Sulphureted	Unimproved.
Kittanning Mineral Spring, Kittanning, Armstrong County.				Calcic, chalybeate.	
Lovett Sulphur Springs, 1 mile from Loretto and near Wildwood Springs, Cambria County.				Sulphureted	Do.
May's Springs, Milligan's Cove, Harrison Township, Bedford County.	2+			Chalybeate	
McCarthy's or Saltillo Mineral Springs, near Saltillo, Huntingdon County.	2+	60	60	Calcic	Resort to limited extent.
McElroy's Spring, Westmoreland Co.				Chalybeate	Local resort.
McVitty's Spring, near Saltillo, Huntingdon County.	1	125	53	Calcic	Used slightly as a resort.
Mineral springs:					
Near Clarion, Clarion County				Chalybeate	Unimportant.
Rose Valley, near Reading, Berks Co				do	
Hanover, York County				do	
Minnequa Springs, near Minnequa, Bradford County.	3	600+	47	Chalybeate, sulphureted.	Resort and water sold to limited extent.
Perry County Warm Spring, Perry County, 14 miles from Harrisburg.	1	5,400	66	Alkaline, calcic.	Has been a resort; abandoned now.
Reed and Lyon White Sulphur Spring, Milligan's Cove, in Harrison Township, near Bedford Springs, Bedford County.	1			Sulpho-chalybeate.	Resort.
Saline Spring (Mr. Peterson's), near Tarentum, Allegheny County.					
Salt springs:					
Near Conemaugh, near Saltsburg, Indiana County.					
Near Alba, Bradford County					
Sulphur springs:					
Near head of Mill Creek, in Mead Township, Crawford County.					
On Ander's Run 2½ miles southwest of Ironton, Warren County.					
On Ben's Creek, Somerset County					
In Toboyne Township, Perry Co	2				
Three Springs, Three Springs, Huntingdon County.	3			Sulphureted, &c	Do.
Wildwood Springs, Loretto, Cambria, County.	8			Chalybeate, &c	Do.
Wolford's White Sulphur Springs, Wolford's Gap, Bedford County.					
Yellow Springs. Chester County					Do.
York Sulphur Springs, York Sulphur Springs, Adams County.	2				Do.

Analyses of mineral springs in Pennsylvania.

Constituents.	Bedford Springs.				
	Sweet Spring.	Magnesia Iron Spring.	Sulphur Spring.	Magnesia Spring.	Large Limestone Spring.
	Grs. per gall.[a]	*Grs. per gall.*[a]	*Grs per gall.*[a]	*Grs. per gall.*[a]	*Grs. per gall.*[a]
Calcium carbonate	0.52	8.47	10.21	10.43	7.09
Magnesium carbonate	0.14	0.59	1.00	0.94	1.88
Manganese carbonate		Trace	Trace	Trace	Trace
Iron carbonate		0.05	0.08	0.04	0.04
Sodium sulphate		0.61	0.51	0.33	
Calcium sulphate		90.46	73.08	99.83	0.58
Potassium sulphate		0.30	0.41	0.18	0.27
Strontium sulphate		0.01		0.13	0.08
Magnesium sulphate		38.68	33.40	39.62	0.29
Barium sulphate				Trace	
Calcium phosphate		0.02	0.02	0.01	Trace
Sodium chloride		0.53	0.37	0.46	0.23
Potassium chloride					Trace
Lithium chloride		Trace	Trace	Trace	
Silica	0.65	0.17	0.54	0.77	0.47
Hydrosulphuric acid		0.01	0.08	Trace	Trace
Carbonic acid	0.31	1.27	2.79	0.56	3.77
Total	1.62	141.17	122.49	153.30	14.70

Constituents.	Bedford Springs.		Hafer's Chalybeate Spring.	Black Barren Spring.	Fayette Spring.
	Chalybeate Spring.	Anderson Spring.			
	Grs. per gall.[b]	*Grs. per gall.*[c]	*Grs. per gall.*[b]	*Grs. per gall.*[d]	*Grs. per gall.*[e]
Sodium carbonate	0.40		0.75		
Potassium carbonate	0.13		0.25		
Calcium carbonate	8.85	8.00	11.34		
Calcium bicarbonate					9.33
Magnesium carbonate	1.20		2.52		
Magnesium bicarbonate					1.53
Manganese carbonate	Trace		0.02		
Manganese bicarbonate					0.05
Iron carbonate	0.44	5.00	0.36		
Iron bicarbonate					1.07
Sodium sulphate				1.21	0.20
Calcium sulphate	2.74	15.00	4.40		0.06
Potassium sulphate					0.11
Magnesium sulphate		80.00		3.24	0.25
Calcium phosphate	0.03		0.03		0.05
Sodium chloride	0.12	10.00	0.18		0.09
Calcium chloride		3.00			
Lithium chloride			Trace		
Alumina					Trace
Silica	0.79		0.86	1.30	1.20
Hydrosulphuric acid	Trace				
Carbonic acid (free)	5.60				0.38
Nitrous acid					Trace
Loss		3.00			
Total	20.30	124.00	20.71	5.75	14.32
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid		74.00			

[a] F. A. Genth, analyst (1878).
[b] F. A. Genth, analyst.
[c] Dr. Church, analyst.
[d] Rand & Cresson, analysts.
[e] F. A. Genth, analyst (1875).

Analyses of mineral springs in Pennsylvania—Continued.

Constituents.	Cresson Springs.			Gettysburg Katalysine Spring.	
	Iron Spring.	Alum Spring.	Magnesia Spring.		
	Grains per gallon.[a]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per imp. gallon.*[b]	*Grains per gallon.*[c]
Sodium carbonate				46.05	
Sodium bicarbonate			1.43		0.70
Potassium bicarbonate			0.21	Trace	
Calcium bicarbonate	3.53		0.02	81.00	16.41
Magnesium bicarbonate			0.41	76.05	0.54
Nickel bicarbonate					Trace
Manganese bicarbonate		Trace	Trace		0.01
Iron bicarbonate	5.04	3.75	0.02	Trace	0.04
Cobalt bicarbonate					Trace
Copper bicarbonate					Trace
Magnesium borate					0.03
Sodium sulphate	1.64	0.70			2.47
Calcium sulphate	48.92	40.20	0.11	53.20	0.83
Potassium sulphate	0.32	0.43			0.21
Strontium sulphate					Trace
Lithium sulphate	Trace	0.05			
Magnesium sulphate	22.58	27.70			0.78
Aluminium sulphate	1.60	21.20			
Barium sulphate					Trace
Iron sulphate	23.48	16.25			
Iron persulphate	Trace	33.39			
Calcium phosphate	0.03	Trace	Trace	Trace	0.01
Sodium chloride	0.04	0.02	1.23	Trace	0.66
Calcium chloride			1.30		
Magnesium chloride			0.56		
Lithium chloride				Trace	Trace
Magnesium bromide				Trace	
Calcium fluoride					0.01
Alumina			0.01		Trace
Silica	1.21	1.87	0.92		
Silicic oxide				10.00	2.03
Carbonic acid (free)			0.66		
Nitrous acid			Trace		
Organic matter					[d]0.71
Impurities					1.10
Total	108.39	145.56	6.88	266.30	26.54

[a] F. A. Genth, analyst (1875).
[b] A. M. Mayer, analyst.
[c] F. A. Genth, analyst (1874).
[d] With nitric acid.

Analyses of mineral springs in Pennsylvania—Continued.

Constituents.	Gettysburg Lithia Spring.			East Clarion Spring.	Kane Geyser Well.
	Grs. per gall.[a]	*Grs. per gall.*[b]	*Grs. per gall.*[c]	*Grs. per gall.*[a]	*Grs. per gall.*[d]
Sodium bicarbonate	3.20	4.97	3.38		
Calcium carbonate					4.14
Calcium bicarbonate	10.71	8.00	9.96	9.80	
Magnesium carbonate					0.36
Magnesium bicarbonate	5.31	7.31	5.83	0.58	
Strontium bicarbonate				Trace	
Manganese carbonate			Trace		Trace
Iron carbonate					7.77
Iron bicarbonate	0.03	0.05	0.04	0.72	
Barium bicarbonate				0.13	
Ammonium nitrate				0.19	
Magnesium nitrate				0.14	
Sodium sulphate		0.20			
Calcium sulphate	0.48	0.25	0.48		35.40
Potassium sulphate	0.15		0.15		
Magnesium sulphate	3.30		3.30		
Calcium phosphate			0.01	Trace	0.07
Sodium chloride	0.28		0.32	336.80	6455.87
Calcium chloride				51.86	2871.32
Potassium chloride		0.11		0.90	2.63
Strontium chloride				0.06	
Magnesium chloride				15.34	555.95
Iron chloride					2.49
Lithium chloride			Trace	Trace	2.66
Barium chloride				1.72	
Magnesium bromide					76.94
Magnesium iodide					0.88
Lithia		Trace			
Alumina			0.02		
Silica			1.76	0.70	0.47
Silicic oxide	1.78	0.17			
Total	25.24	21.06	25.25	418.94	10016.94

Constituents.	Kittanning Mineral Spring.	May's Chalybeate Spring.	McCarthy's Springs.	McVitty's Spring.	Mineral Spring, Hanover.
	Grs. per gall.[e]	*Grs. per gall.*[e]	*Grs. per gall.*[e]	*Grs. per gall.*[e]	*Grs. per gall.*[f]
Sodium carbonate					Trace
Calcium carbonate		6.67			029
Calcium bicarbonate	16.05		22.24	9.84	
Magnesium carbonate		1.18			
Magnesium bicarbonate			0.88	1.87	
Manganese bicarbonate	0.25				
Iron carbonate		0.06			
Iron bicarbonate			0.08	0.14	
Sodium sulphate	8.73	1.81	7.79	1.01	
Calcium sulphate	65.12	4.55	72.20		
Aluminium sulphate	1.53				
Potassium sulphate	0.91	0.44	0.22	0.16	
Magnesium sulphate	26.85	2.25	41.80	Trace	042
Iron sulphate	24.49				
Calcium phosphate	0.11	0.05	Trace	Trace	
Sodium chloride	0.65	0.46	0.21	0.06	
Lithium chloride		Trace			
Magnesium protoxide					021
Iron protoxide					184
Alumina					016
Silica	1.17	0.33	1.17	0.59	
Hydrosulphuric acid			0.02	0.02	
Carbonic acid		5.46			
Total	145.86	23.26	146.61	13.69	292

[a] F. A. Genth, analyst (1874).
[b] O. Oldsburg, analyst.
[c] F. A. Genth, analyst (1875).
[d] F. A. Genth, analyst (1880).
[e] F. A. Genth, analyst.
[f] Prof. Hollenbush, analyst.

Analyses of mineral springs in Pennsylvania—Continued.

Constituents.	Kane Sulphur Spring.	Minnequa Springs.		Reed and Lyon White Sulphur Spring.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[a]
Sodium carbonate	1.44		1.09	0.54
Sodium bicarbonate		1.33		
Potassium carbonate	0.46			
Potassium bicarbonate		0.14		
Calcium carbonate	4.78		0.73	5.58
Calcium bicarbonate		6.53		
Magnesium carbonate	0.85		1.27	1.29
Magnesium bicarbonate		1.59		
Nickel carbonate	Trace			
Manganese carbonate	0.02			
Manganese bicarbonate	Trace	0.06		
Zinc bicarbonate		0.01		
Iron carbonate	0.10	Trace		0.43
Iron bicarbonate		0.04		
Barium bicarbonate		0.01		
Magnesium borate		0.08		
Ammonium nitrate		Trace		
Ammonium nitrite				
Sodium sulphate				1.01
Calcium sulphate	0.07		0.49	0.36
Potassium sulphate				0.22
Magnesium sulphate				0.98
Barium sulphate		Trace		
Calcium phosphate	0.01	0.01		Trace
Sodium chloride	0.77	0.19	1.03	0.19
Potassium chloride			Trace	
Lithium chloride	Trace	Trace		Trace
Iron protoxide			3.70	
Alumina	0.03	Trace		
Silica	0.60	0.75		1.81
Sulphur			1.34	
Hydrosulphuric acid	Trace	0.01		0.06
Carbonic acid	3.19			1.29
Organic matter			0.74	
Total	12.32	10.75	10.39	13.76

Constituents.	Sulphur Spring, Ander's Run.	Blossburg Springs.	Perry County Warm Spring.	Guylyck and Gaylord's Spring.
	Grains per gallon.[a]	*Grains per gallon.*[a]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate	7.49			
Potassium carbonate	0.51			
Calcium carbonate	4.75		2.67	
Magnesium carbonate	2.47		1.94	
Iron carbonate	0.18			
Sodium sulphate		0.27		0.25
Calcium sulphate	0.61	23.18		17.91
Aluminium sulphate		6.58		0.55
Potassium sulphate		0.24		
Lithium sulphate		0.12		
Magnesium sulphate		13.10		15.55
Manganese sulphate		1.83		
Nickel sulphate		0.36		
Cobalt sulphate		0.03		
Iron sulphate				73.06
Iron persulphate		31.32		
Iron phosphate		0.33		
Sodium chloride	0.98	0.10		
Alkaline salts (chiefly chlorides)			1.09	
Silica	0.61	2.15	0.60	0.56
Sulphuric acid		5.64		3.10
Carbonic acid	6.60			
Organic matter			2.90	
Total	24.20	85.20	9.20	110.98

[a] F. A. Genth, analyst.
[b] F. A. Genth, analyst (1875).
[c] Dr. Gregg, analyst.
[d] James C. Booth, analyst (1850).
[e] S. A. Lattimore, analyst (1885).

SOUTHERN ATLANTIC STATES.

The general geologic features of the Southern Atlantic States are very much like those of the Northern Atlantic division and the mineral springs are also similar. Sulphureted waters and chalybeate springs are most prominent in both. There is, however, this difference: thermal springs, which are of infrequent occurrence in the northern section, are quite numerous in the southern. This is probably due to the fact that faulted strata are more prevalent in the Southern Appalachians than in the Northern, which recent observations by members of the United States Geological Survey (most of them still unpublished) seem to indicate is the case. The connection of many noted European springs with dislocated strata has long been known, and Prof. W. B. Rogers also called attention to the same state of things in Virginia, in his memoir On the Connection of Thermal Springs in Virginia with Anticlinal Axes and Faults, published (1840–1842) in the Transactions of the Association of American Geologists and Naturalists.

The Southern Atlantic States have more springs that are utilized for places of resort than has any other section, except the Southern Central States.

Virginia stands at the head of the section in this respect. Only one State (Tennessee) in any other section has more, and in the latter case probably more of the localities are used simply as local resorts.

A large number of the springs in this section are still unknown so far as a definite statement of their chemical constituents is concerned, but every year adds to the list of analyses.

Summary for Southern Atlantic States.

States.	Number of spring localities.	Number of individual springs.	Number of springs analyzed.	Number of spring localities utilised as resorts.	Number of springs used commercially.	Total number of analyses.
Delaware	5	5	0	0	0	0
Maryland	29	101	4	5	1	4
District of Columbia	2	4	0	0	0	0
Virginia	97	307	75	54	21	87
West Virginia	38	69	20	15	6	23
North Carolina	77	175	19	33	8	29
South Carolina	31	39	6	8	3	6
Georgia	55	290	20	26	3	21
Florida	37	58	4	11	0	4
Total	371	1,048	148	152	42	164

DELAWARE.

From the few reports of geological surveys of Delaware we learn that chalybeate springs are numerous, as would naturally be expected from its geological structure.

They are, however, of comparatively little importance, only one, so far as learned, having ever been utilized as a place of resort, viz, the Brandywine Chalybeate Spring, which has long been abandoned.

The table includes all the springs of which mention could be obtained by correspondence.

Mineral springs of Delaware.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Brandywine Chalybeate Spring, Faulkland, west of Wilmington, New Castle County.	1		°	Chalybeate	Once improved and used as a resort.
Mineral springs:					
Near Dagsborough, Sussex County.					Unimproved and unimportant.
Two miles from Dover, Kent Co				Chalybeate	Unimproved.
Ten miles from Dover, Kent Co.				Sulphureted	Do.
At Smyrna, Kent County					Unimproved and filled up.

MARYLAND.

The general works on mineral springs give no space to Maryland and Dr. Pepper's list includes but one locality, viz, the Carroll White Sulphur Springs of Alleghany County, which at present, so far as we can learn, is not resorted to.

There are several localities that were once used extensively, but have fallen into disuse.

The proximity of many of the springs to those of Virginia has probably caused them to be neglected. Still there are several places of resort, and the water of one—the Strontia Well of Brooklandville—is used commercially. In the eastern part of the State the springs are mainly chalybeate, the majority of them unimproved and unimportant.

Mineral springs of Maryland.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Barren Creek Springs, Barren Creek Springs, Wicomico County.				Chalybeate	Once used extensively.
Belinda Spring, 14 miles from Sharpsburg, Washington County.	1				Once a resort but now unimproved.
Bentley's Springs, Bentley's Springs, Baltimore County.	50			Alkaline, chalybeate, &c.	Resort.
Bevy Springs, old Carroll estate, Takoma Park, Montgomery County.	7			Chalybeate, &c.	
Bingham Spring, 3½ miles northeast of Wittman, Talbot County.					Unimproved.
Blue Sulphur Springs, Piney Grove, Alleghany County.	5				Do.
Calcic springs:					
Near Hagerstown, Washington Co.					Limestone springs are common.
Carroll White Sulphur Springs, between Green Ridge and Polish Mountain, Alleghany County.	4		48	Sulphureted	
Chalybeate springs:					
Six miles from Easton, Talbot Co.					
Near Hancock, Washington Co	2				Unimproved.
Near New Windsor, Carroll Co					
In Queen Anne's County					
Ennall's Spring, south of Trappe, Talbot County.					Do.
Flint Stone Mineral Springs, Flint Stone, Alleghany County.		100	Cold	Saline	Used locally.
Goldsborough Springs, 2 miles southeast of Dundee, Talbot County.					Unimproved.
Lloyd's Spring, Near Lloyd's Landing, Talbot County.					Do.
Mineral springs:					
Near Clear Spring, Washington Co.					
At Mineral Spring, Garrett County.	1			Sulpho-chalybeate.	Do.
At Green Spring Furnace, Washington County.	2			Saline, chalybeate, and lithia.	
Outram Springs, south of Easton, Talbot County.					Do.
Ridgeway's Springs, west of Easton, Talbot County.					Do.
River Springs, River Springs, Saint Mary's County.	9	100		Chalybeate, &c	Resort.
Spa Spring, Bladensburg, Prince George's County.	1	180	56	Saline, chalybeate.	Do.
Strontia Mineral Spring, Brooklandville, Baltimore County.	1	350	50	do	Used commercially.
Sulphur springs:					
At Sulphur Springs Station, B. & P. R. R., Baltimore County.					Unimportant and unimproved.
Near Williamsport, Washington County.					Unimproved.
Near Indian Springs, Washington County.					Unimproved and unimportant.
Warm Springs, 1 mile from Flint Stone, Alleghany County.			64		
Windsor Sulphur Springs, near Windsor, Carroll County.				Sulphureted, &c.	Resort.

Analyses of mineral springs in Maryland.

Constituents.	Strontia Mineral Spring.	Bentley's Springs.		Flint Stone Mineral Springs.
		Chalybeate Spring.	Station Spring.	
	Parts in 100,000.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Sodium carbonate		0.46	0.37	
Magnesium carbonate		0.68	0.26	
Calcium carbonate		0.64	0.34	
Calcium bicarbonate	6.75			
Strontium bicarbonate	1.86			
Iron carbonate		0.89		
Iron bicarbonate	0.88			
Calcium sulphate		0.35	0.30	
Strontium sulphate	0.22			
Sodium nitrate	1.43			
Potassium nitrate	4.66			
Sodium chloride	12.87	0.27	0.19	
Magnesium chloride	6.72			
Calcium chloride	35.46			
Iron			Trace	
Alumina	1.86		0.02	
Loss		0.08		
Silicic acid	2.05	0.43	0.33	
Organic matter	Trace	0.91	0.37	
Magnesia				12.74
Lime				38.16
Sulphuric acid				71.68
Carbonic acid, chlorine, potash, and soda.				51.42
Phosphoric acid, iodine, ammonia, and organic matter.	Trace			
Total	74.76	4.66	2.18	174.00
Gases.	*Cubic inches.*			
Oxygen	0.82			
Nitrogen	1.22			
Carbonic acid	3.50			

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[a] W. Simon, analyst.

[b] W. E. A. Aiken, analyst (1867).

[c] Hector Humphrey and David Stewart, analysts.

DISTRICT OF COLUMBIA.

A number of the wells and springs within the limits of the District are chalybeate; but none, even the strongest, is of much importance and the number is so small that no detailed list has been made.

At Uniontown, or Anacostia, opposite Washington, and also near Le Droit Park, in the northeastern part, chalybeate springs exist. A well on Louisiana avenue, between Ninth and Tenth streets, in Washington, is said to be quite strongly impregnated with iron. There are several other localities within the city limits that are said to have chalybeate springs or wells. No analyses have been made.

VIRGINIA.

Virginia occupies the same position among the Southern Atlantic States that New York does among the Northern Atlantic States, in respect to both the number and the variety of her mineral springs. More than fifty localities are places of resort, some of them among the most famous in the country, and the waters of more than twenty are used commercially. Although the spring area proper is in the Appalachian region, mineral springs are also found in the more level country that stretches towards the coast from the foot of the Blue Ridge. Here the springs are largely chalybeate, as would naturally be expected. The thermal springs are confined to the mountain region. A large proportion of the springs are sulphureted, as is the case with so many springs in the adjoining States.

The literature of the Virginia springs is quite extensive. Prof. W. B. Rogers, in his geological report on the State, devotes considerable space to the mineral springs. Since his report a number of books have been published, among them those of Burke and of Moorman. These have all been consulted in the preparation of the following table. Boyd's Resources of Southwestern Virginia, published in 1881, has also furnished much information; but by far the greatest amount has been obtained in answer to circulars and letters sent to various portions of the State. Eighty-seven analyses are given in the table, the number of springs analyzed being seventy-five, which is only about one-quarter of the springs included in the list. This number is, however, slightly greater than the proportion in New York.

Mineral springs in Virginia.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Alleghany Springs, Alleghany Spring, Montgomery County.	3	125	....	Saline, calcic....	Used commercially and as a resort.
Alum Springs of Rockbridge County, Goshen Bridge, Rockbridge Co.	5	....	....	....	Do.
Alum Well, 14 miles northwest of Abingdon, Washington County.	....	....	....	....	Local resort.
Amelia Springs, near Jetersville, Amelia County.	8	....	....	....	Once a resort.
Bath Alum Springs, Bath Alum, Bath County.	8	....	....	Chalybeate.....	Used commercially and as a resort.
Bedford Alum and Iron Springs, Bedford Springs, Campbell County.	2	....	56	....do	Has been used commercially and as a resort.
Black Rock Springs, in Blue Ridge, Augusta County.	....	....	....	....do	Formerly frequented by private parties.
Blue Ridge Springs, Blue Ridge Springs, Botetourt County.	5	375	50 to 60	Saline, calcic....	Used commercially and as a resort.
Bolar Springs, 4 miles from Cleek's Mills, Bath County.	....	....	....	....	Unimproved.
Botetourt Springs (or Johnson's Springs), 8 miles east of Salem, Roanoke County.	....	....	....	Sulphureted	Now the site of Hollins Institute.
Buckingham White Sulphur Springs, 12 miles from Buckingham Court-House, Buckingham County.	2	120	....	Saline, sulphureted, and chalybeate.	Resort.
Buffalo Lithia Springs, Buffalo Lithia Springs, Mecklenburg County.	3	180	65	Alkaline, calcic, and chalybeate.	Used commercially and as a resort.
Burner's Springs (Seven Springs), near Woodstock, Shenandoah Co.	7	....	....	....	Resort.
Cecil's Alum Springs, Pulaski County	....	....	....	....	
Cedar Bluff Sulphur Springs, Cedar Bluff, Tazewell County.	2	16	....	Sulphureted	Do.
Chilhowee or Holston Sulphur Springs, 10 miles southwest of Marion, Smyth County.	....	....	....	....	Local resort.
Church Hill Alum Springs, near Richmond, Henrico County.	....	....	....	Chalybeate	
Cistern Lick Springs, 18 miles northeast of Warm Springs, Bath Co.	....	....	....	....	Very slightly improved.
Claypole's Chalybeate Spring, Burke's Garden, Tazewell County.	....	....	....	....	Used locally for medicinal purposes.
Clifton Springs, near Clifton Forge, Alleghany County.	4	....	58 to 62	Alkaline, chalybeate.	Resort.
Cold Sulphur Springs, near Goshen Bridge, Rockbridge County.	2	300+	52	Saline, calcic....	Used to some extent commercially and as a resort.
Coyner's Sulphur Springs (post office address, Bonsack's, Roanoke Co.), Botetourt County.	5	75+	52 to 54	Sulphureted	Resort.
Crystal Sulphur Springs, 18 miles west of Staunton, Augusta County.	2	60	....	....do	Do.
Daggers or Dibrell Spring, Daggers, Botetourt County.	....	....	....	....do	Do.
Dickson's or Callaghan's Sulphur Spring, Callaghan's, Alleghany Co.	....	....	54	....	
Dillard's Springs, near Ward's Springs, Pittsylvania County.	....	....	....	Sulphureted	
Edmondson's Spring, or Lebanon White Sulphur Springs, Jennings Gap Road, Augusta County.	....	....	50 to 54	....	
Falling Spring, 9 miles northeast of Covington, Alleghany County.	....	....	....	....	Unimproved.
Farmville Lithia Springs, Cumberland County, opposite Farmville, Prince Edward County.	16	[a]110	....	Carbonated, saline.	Used commercially.
Fauquier White Sulphur Spring, Fauquier Springs, Fauquier Co.	1	175	56	Alkaline, carbonated.	Resort.
Grayson's Sulphur Springs, Carroll Co., 20 miles south of Wytheville.	4	....	47 to 48	Sulphureted	Do.

[a] Flow of four springs.

Mineral springs in Virginia—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Hagan's Springs, near Clinch, Scott County.	8	2	° 49	Chalybeate and sulphureted.	Local resort.
Harrison's Mineral Spring, Tazewell County.				Chalybeate	Used for medicinal purposes.
Healing Springs, Healing Springs, Bath County.	4		85 to 88	Alkaline, calcic.	Used commercially and as a resort.
Holston Springs, 2 miles from Big Moccasin Gap, Scott County.	4		61½ to 68½	Saline	
Hot Springs, Hot Springs, Bath Co.	20		50 to 110	Saline, calcic	Resort.
Huguenot Springs, Powhatan County, 17 miles from Richmond.	3			Sulphureted and chalybeate.	Do.
Iron Hill Springs, near Alleghany Station, Alleghany County.	6				Was once a resort.
Jordan Alum Springs, near Rockbridge Alum Springs, Rockbridge County.	6		52½ to 58.2	Chalybeate	Resort.
Jordan's White Sulphur Springs, 1½ miles from Stephenson Depot, Frederick County.	2		57	Sulphureted and chalybeate.	Used commercially and as a resort.
Kern's Springs, 6 miles northwest of Woodstock, Shenandoah County.	6			Chalybeate	Used locally as a resort.
Kimberling Springs, Bland County, 28 miles from Wytheville.					Local resort.
Liberty Springs, 2½ miles northwest of Rawley Springs, Rockingham Co.					Resort.
Lithia Springs, 3 miles southwest of Abingdon, Washington County.					Unimproved.
Lone Fountain, Augusta County					Used locally.
Magnesia Springs, Ash Grove, near Great Falls of Potomac, Fairfax Co.	4	400	60	Chalybeate	Unimproved.
Massanetta Mineral Springs (formerly Taylor's Springs), near Harrisonburg, Rockingham County.	2	30,000+	60	Calcic, alkaline	Used commercially and as a resort.
McHenry's Thermal Spring, Scott Co			68		
Millborough Springs, Millborough Springs, Bath County.	2		48 to 60	Sulphureted and chalybeate.	Resort.
Mineral springs:					
Eight miles from Wytheville Springs (Cove Lithia Springs), Wythe County.					Do.
Near Mandota, Washington County.	5			Sulphureted and chalybeate.	Unimproved.
Near Beech Spring, Lee County	3			do	
Poor Valley, 9 miles northwest of Jonesville, Lee County.	8				
Three miles north of Jonesville, Lee County.	2	75			Used locally.
Near Farmwell Station, Loudoun County.	8				Unimproved.
At Giggett's, near Palmer's Springs, Mecklenburg Co.					Do.
Montgomery White Sulphur Springs, Montgomery Springs, Montgomery County.				Sulphureted	Resort.
Mungel's Springs, 9 miles northwest of Abingdon, Washington County.	4	70		Sulphureted and chalybeate.	Do.
Mustard's Mineral Springs, near Witten's Mills, Tazewell County.				Sulphureted	Used for medicinal purposes.
New River White Sulphur Springs (Eggleston Springs), near Staytide, Giles County.	3	150	85	do	Resort.
Orkney Springs, Orkney Springs, Shenandoah County.	23	572+	58.6–59.7	Alkaline, calcic.	Do.
Palmer's Springs, Palmer's Springs, Mecklenburg County.	2				Used locally.
Powhatan Lithia and Alum Springs, near Ballsville, Powhatan County.	4		64	Chalybeate, &c.	Used commercially.
Preston's Spring, Montgomery Co			54		
Pulaski Alum Springs, Dublin, Pulaski County.	3		58	Chalybeate	Used commercially and as a resort.
Rawley Springs, Rawley Springs, Rockingham County.	8	178	51.8–54.6	do	Do.

Mineral springs in Virginia—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks.
Roanoke Red Sulphur Springs, near Salem, Roanoke County.	4	1,278	53 to 60	Sulphureted and chalybeate.	Resort.
Rockbridge Alum Springs, Rockbridge Alum Springs, Rockbridge County.	4		50 to 56	Chalybeate	Used commercially and as a resort.
Rockbridge Baths, Rockbridge Baths, Rockbridge County.			74	Alkaline	Resort.
Rock Enon Springs (Capper's), Rock Enon Springs, Frederick County.	8			Alkaline and saline, chalybeate and sulphureted.	Used commercially and as a resort.
Rockingham Virginia Springs, near McGaheysville, Rockingham Co.	10	780	40 to 58	Saline, chalybeate.	Do.
Seven Springs, near Abingdon, 2 miles from Glade Spring Depot, Washington County.	7			Chalybeate	Used commercially.
Sharon Springs, Sharon Springs, Bland County.	3			do	Resort.
Shenandoah Alum Springs, Shenandoah Alum Springs, Shenandoah Co.	10	157	56 to 70	do	Used commercially and as a resort.
Silcott's Springs, Silcott Springs, Loudoun County.	1			do	Unimproved.
Snake Run Spring, 20 miles southwest of Covington, Alleghany Co.				do	Resort.
Stafford Springs, Stafford Store, Stafford County.					Used to some extent; has been unimproved for a long time.
Stribling or Augusta Springs, Stribling Springs, Augusta County.	6				Used commercially and as a resort.
Sudley Springs, Sudley Springs, Prince William County.	2	52+	58	Chalybeate	Once a resort.
Sulphur Spring, Russell County, 24 miles northwest of Abingdon.	1				Unimproved.
Sulphur and Chalybeate Springs, near Beech Spring, Lee County.	3				
Sweet Chalybeate Springs (Red Sweet Springs), Sweet Chalybeate, Alleghany County.	4	800+	75 to 79	Calcic, chalybeate.	Resort.
Tally's Springs, 2 miles from Palmer's Springs, Mecklenburg Co.					Has a local reputation.
Tazewell Sulphur Springs, 5 miles northwest of Jeffersonville, Tazewell County.	4			Sulphureted	Was a resort prior to the war.
Union Springs, 3 miles south of Rawley Springs, Rockingham County.					
Valley View Springs, near Newmarket, Shenandoah County.				Sulphureted, chalybeate.	Resort.
Variety Springs, near Pond Gap, Augusta County.	4	160+		Chalybeate, &c.	Do.
Wallawhatoola Alum Springs, 3½ miles from Millboro Depot, Bath County.	2	75+	56	Saline, chalybeate.	Used commercially and as a resort.
Warm Sulphur Springs, Warm Springs, Bath County.		360,000	96 to 98	Calcic	Resort.
Washington Springs, near Glade Spring, Washington County				Chalybeate	Do.
Wayland Spring, near Jennings' Ordinary, Nottoway County.				do	Local resort.
White Sulphur Spring, Big Stone Gap, Wise County.	1				Used to a limited extent as a resort.
White Sulphur Springs, Tazewell Co.					
Wilson's Thermal Spring					Probably same as Daggers Spring.
Wolf Trap, Lithia Springs (well), Wolf Trap, Halifax Co.			59	Alkaline, calcic.	Used commercially.
Wytheville Springs, Wytheville, Wythe County.				Chalybeate	Resort.
Yellow Sulphur Springs, near Christiansburg, Montgomery County.		150	55	Calcic, saline, sulphur.	Do.

Analyses of mineral springs in Virginia.

Constituents.	Allegheny Springs.	Bath Alum Springs.				Clifton Springs.	
		Spring No. 1.	Spring No. 2.	Spring No. 3.	Cave Springs.	Spring No. 1.	Spring No. 2.
	Grains per gall.[a]	*Grains per gall.*[b]	*Grains per gall.*[c]	*Grains per gall.*[b]	*Grains per gall.*[c]	*Grs. per imp. gall.*[d]	*Grs. per imp. gall.*[d]
Calcium carbonate	3.61						
Calcium bicarbonate					0.69		
Magnesium carbonate	0.36						
Magnesium bicarbonate					1.98		
Lithium carbonate	Trace						
Strontium carbonate	0.06						
Barium carbonate	0.02						
Manganese carbonate	0.06						
Manganese bicarbonate					0.64		
Iron carbonate	0.16						
Iron bicarbonate					2.18		
Cobalt carbonate	Trace						
Zinc carbonate	Trace						
Copper carbonate	Trace						
Lead carbonate	Trace						
Sodium sulphate	1.72		1.13		0.30		
Calcium sulphate	115.29	3.80	1.71		0.32		
Lithium sulphate			Trace		Trace		
Magnesium sulphate	50.88	2.82	0.46				
Potassium sulphate	3.70		0.34	0.26	0.17		
Aluminium sulphate			29.99		0.02		
Ammonium sulphate			Trace				
Manganese sulphate			0.03				
Iron persulphate			26.78				
Magnesium nitrate	3.22						
Ammonium nitrate	0.56						
Calcium phosphate					Trace		
Aluminium phosphate	0.03			3.15			
Sodium silicate		2.02					
Aluminium silicate	0.21						
Ammonium crenate		1.85		1.77			
Sodium chloride	0.28	0.17	0.11				
Calcium chloride					0.06		
Calcium fluoride	0.02						
Soda						0.584	4.182
Magnesia				1.28		0.825	3.2[illegible]
Potash						0.153	0.648
Lime						1.226	21.830
Lithia						Trace	Trace
Antimonium teroxide	Trace						
Iron oxide		14.52		21.77		1.109	Trace
Manganese protoxide						Trace	
Alumina		10.29		12.29		0.076	
Silica	0.88		1.95		0.45	0.728	1.177
Chlorine						0.052	0.765
Phosphoric acid							Trace
Sulphuric acid		5.81	2.88	7.88		0.721	2.236
Carbonic acid		4.14		3.85		2.069	22.373
Crenic acid	Trace						
Apocrenic acid	Trace			2.54			
Organic acid						[e]0.422	
Organic matter	2.00						Trace
Oxygen added to sodium		0.02					
Total	183.06	45.44	65.38	54.79	6.81		
Gases.						*Cu. in.*	*Cu. in.*
Carbonic acid	4.56	4.652				6.013	5.018
Sulphureted hydrogen	Trace						
Oxygen						1.847	10.210
Nitrogen						8.955	

[a] F. A. Genth, analyst.
[b] Hayes, analyst.
[c] W. H. Taylor, analyst.
[d] J. L. Campbell, analyst (1877).
[e] With ammonia.

Analyses of mineral springs in Virginia—Continued.

Constituents.	Bedford Alum and Iron Springs.		Blue Ridge Springs.	Buffalo Lithia Springs.			Cold Sulphur Springs.
				Spring No. 1.	Spring No. 2.	Spring No. 3.	
Solids.	*Grains per gall.*[a]	*Grains per gall.*[b]	*Grains per gall.*[c]	*Grains pr. imp. gall.*[d]	*Grains pr. imp. gall.*[d]	*Grains pr. imp. gall.*[d]	*Grains per gall.*
Calcium bicarbonate	....	....	5.44	39.28	14.96	2.52	1.84
Magnesium carbonate	....	....	....	....	....	....	1.78
Magnesium bicarbonate	....	....	3.01	....	....	....	....
Potassium carbonate	....	....	....	....	29.30	1.85	....
Lithium bicarbonate	....	....	....	1.48	2.25	....	....
Barium bicarbonate	....	....	....	....	1.75	....	....
Iron carbonate	....	....	....	....	....	....	0.02
Iron bicarbonate	....	....	0.41	0.50	0.30	3.77	....
Sodium sulphate	0.87	....	0.97	....	....	....	2.46
Calcium sulphate	4.99	18.67	100.22	19.25	33.07	2.35	2.91
Lithium sulphate	0.24	....	....	....	....	....	....
Magnesium sulphate	12.58	12.66	47.56	1.53	0.89	0.15	0.29
Potassium sulphate	0.71	10.16	0.40	0.46	....	....	....
Aluminium sulphate	24.18	7.24	....	8.18	9.07	3.04	0.25
Manganese sulphate	0.19	....	....	....	....	....	....
Iron protosulphate	0.59	23.46	....	....	....	....	....
Iron persulphate	19.26	....	....	....	....	....	....
Nickel sulphate	0.04	....	....	....	....	....	....
Cobalt sulphate	0.06	....	....	....	....	....	....
Copper sulphate	0.06	....	....	....	....	....	....
Zinc sulphate	0.07	....	....	....	....	....	....
Magnesium nitrate	0.27	....	....	....	....	....	....
Ammonium nitrate	0.24	....	....	....	....	....	....
Calcium phosphate	0.30	....	....	....	....	....	....
Phosphates	....	....	....	....	....	....	Trace
Sodium silicate	....	....	....	....	....	....	1.48
Sodium chloride	0.23	....	0.25	1.26	4.92	0.22	....
Calcium chloride	....	....	....	....	....	....	0.12
Calcium fluoride	Trace	....	....	....	....	....	....
Lithia	....	....	....	....	....	Trace	....
Alumina	....	....	0.14	....	....	....	....
Silica	1.69	....	1.26	1.72	1.87	0.57	....
Iodine	....	....	....	Trace	Trace	....	....
Phosphoric acid	....	....	....	Trace	Trace	Trace	....
Sulphuric acid	4.02	19.98	....	....	....	....	....
Organic matter	0.29	....	....	Trace	Trace	Trace	0.32
Total	70.88	92.17	159.66	73.66	98.38	14.47	11.47
Gases.				*Cubic in.*	*Cubic in.*	*Cubic in.*	
Carbonic acid	....	....	....	69.1	59.2	11.6	....
Sulphureted hydrogen	....	....	....	5.9	8.8	3.4	....
Oxygen	1.32	....	....	....	....	....	....
Nitrogen	3.33	....	....	....	....	....	....
Carbon dioxide	6.98	....	....	....	....	....	....

[a] M. B. Hardin, analyst (1877).

[b] William Gilham, analyst.

[c] F. A. Genth, analyst.

[d] W. P. Tonry, analyst (1874).

Analyses of mineral springs in Virginia—Continued.

Constituents.	Church Hill Alum Springs.	Farmville Lithia Springs, No. 2.	Fauquier White Sulphur Spring.	Dickson's Sulphur Spring.	McHenry's Thermal Spring.	Wilson's Thermal Spring.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains in 200 cu. in.*[d]	*Grains in 100 cu. in.*[d]	*Grains in 100 cu. in.*[d]
Sodium carbonate				2.26		
Calcium carbonate				2.48	6.34	5.00
Calcium bicarbonate		1.33	7.88			
Magnesium carbonate				1.50	1.54	0.52
Magnesium bicarbonate		4.49	2.47			
Lithium carbonate		1.99				
Manganous carbonate		Trace				
Ferrous carbonate		1.26				
Sodium sulphate	1.94	3.59			3.77	3.53
Calcium sulphate	88.83	1.81	3.39		7.83	8.09
Magnesium sulphate	86.07				0.25	1.30
Potassium sulphate	2.44	0.18	[e]1.63			
Aluminium persulphate	72.93					
Ammonium sulphate	0.64					
Iron sulphate			[f]2.14			
Iron bisulphate	83.35					
Iron protosulphate	24.18					
Iron persulphate	51.26					
Sodium chloride	4.62	5.30	3.75	0.05	0.68	Little
Magnesium chloride						
Calcium chloride						
Potassium chloride				Trace		
Calcium and magnesium phosphate.			0.64			
Iron peroxide				0.03	Trace	Trace
Alumina		2.52				
Silica	10.43	3.92		0.96		(g)
Iodine		Trace				
Phosphoric acid	Trace					
Sulphuric acid		Trace				
Organic matter		Trace		Little	Little	(g)
Gaseous matter, &c			0.10			
Loss				0.19		
Total	426.69	26.39	22.00	7.47	20.41	22.85
Gases.		*Cubic in.*	*Cubic in.*			
Carbonic acid		74.2	11.00		Undeterm'd	Undeterm'd
Sulphureted hydrogen			Little			

Constituents.	Edmondson's Spring.	Holston Springs.	Mineral Springs near Farmwell Station.		Healing Springs.	
			No. 1.	No. 3.	Old Spring.	New Spring.
	Grains in 200 cu. in.[d]	*Grains per gallon.*[h]	*Grams per liter.*[i]	*Grams per liter.*[i]	*Grains per gallon.*[j]	*Grains per gallon.*[j]
Sodium carbonate	1.82					
Calcium carbonate	2.77	6.40	0.1319	0.1107	17.90	18.72
Calcium bicarbonate			0.1100	0.1438		
Magnesium carbonate	(g)				1.25	1.96
Iron carbonate					0.07	0.28
Sodium sulphate	Trace	Trace	0.2355	0.2543		
Calcium sulphate		20.48	1.5052	1.6363	1.32	1.26
Magnesium sulphate		12.72	0.0750	0.0975	7.25	7.39
Potassium sulphate					2.21	2.53
Aluminium sulphate		Trace				
Ammonium sulphate					0.23	0.23
Iron sulphate					0.18	0.10
Aluminium phosphate		Trace				
Sodium chloride	0.12	[k]1.52	0.0104	0.0244	0.27	2.89
Potassium chloride			0.0067	0.0057	0.24	0.25
Iron peroxide	(g)					
Alumina			0.0070	0.0105		
Silica	(g)		0.0210	0.0110	1.89	1.83
Bromine					Trace	Trace
Iodine					Trace	Trace
Carbonic acid					2.20	2.29
Organic acid					0.86	0.88
Organic matter	(g)					
Loss			0.0040			
Sulphureted hydrogen					Trace	Trace
Total	7.38	41.12	2.1067	2.2942	34.87	40.60

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[a] J. C. Booth, analyst.

[b] E. T. Fristoe, analyst (1879).

[c] Thomas Antisell, analyst (1878).

[d] W. B. Rogers, analyst.

[e] With sodium sulphate.

[f] With iron phosphate.

[g] Quantities not given.

[h] Hayden, analyst.

[i] R. B. Riggs, analyst (1886).

[j] W. E. Aiken, analyst (1868).

[k] With ammonium chloride.

Analyses of mineral springs in Virginia—Continued.

Constituents.	Hot Springs.				
	Boiler Bath (Old Ladies' Boiler Bath).	Hot Spout Bath.	Octagon Bath.	New Hot Spring.	Sulphur Bath or Ladies' Sulphur Bath.
	Gram per liter.[a]	*Gram per liter.*[a]	*Gram per liter.*[a]	*Gram per liter.*[a]	*Gram per liter.*[a]
Calcium carbonate	0.2355	0.2390	0.2340	0.2272	0.2355
Magnesium carbonate	0.1249	0.1201	0.1218	0.1228	0.1155
Sodium sulphate	0.0370	0.0281	0.0296	0.0278	0.0420
Calcium sulphate	0.1407	0.1424	0.1504	0.1401	0.1278
Potassium sulphate	0.0138	0.0187	0.0185	0.0212	0.0158
Potassium chloride	0.0105	0.0092	0.0086	0.0061	0.0068
Alumina	0.0020	0.0025	0.0035	0.0060	0.0065
Silica	0.0275	0.0235	0.0255	0.0235	0.0230
Bromine	Trace	Trace	....	....	....
Loss	0.0056	0.0090	0.0021	....	0.0046
Total	0.5975	0.5925	0.5940	0.5747	0.5775

Constituents.	Hot Springs.				
	Magnesian Spring.	Boiler Spring or Ladies' Boiler Bath.		Ladies' Sulphur Bath.	Gentlemen's Pleasure Bath or Magnesia Spring.
Solids.	*Gram per liter.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[c]
Calcium carbonate	0.1845	17.40	17.34	16.44	9.48
Magnesium carbonate	0.0781	....	2.68	2.80	2.02
Iron carbonate	....	....	0.11	0.06	0.08
Sodium sulphate	0.0201	3.64	1.02	1.01	0.85
Calcium sulphate	0.0744	5.48	1.74	2.10	3.02
Magnesium sulphate	....	2.05	5.66	5.10	1.06
Potassium sulphate	0.0109	....	1.35	1.82	0.57
Sodium chloride	....	1.83	0.12	0.14	0.13
Potassium chloride	0.0042	....	1.60	0.17	0.16
Silica	0.0120	0.18	1.74	1.37	0.69
Loss	0.0038	....	....	....	....
Total	0.3825	30.58	33.36	31.01	18.09
Gases.		*Cubic inches in 100 cu. in.*			
Carbonic acid	....	11.007	....	....	....
Sulphureted hydrogen	....	Trace	....	....	....
Oxygen	....	0.220	....	....	....
Nitrogen	....	1.790	....	....	....

[a] F. W. Clarke, analyst (1884). [b] W. B. Rogers, analyst. [c] William Gilham, analyst (1866).

Analyses of mineral springs in Virginia—Continued.

Constituents.	Jordan Alum Springs.						
	Chalybeate Spring.	Alum Spring.	Spring No. 2.	Spring No. 3.	Spring No. 4.	Spring No. 5.	Spring No. 6.
Solids.	***Grains per gall.***[a]	***Grains per gall.***[b]	***Grains per gall.***[a]	***Grains per gall.***[a]	***Grains per gall.***[a]	***Grains per gall.***[a]	***Grains per gall.***[a]
Magnesium carbonate	0.74						
Manganese carbonate	0.04						
Iron carbonate	0.70						
Sodium sulphate	0.14	0.17	0.25	0.19	0.23	0.32	0.24
Calcium sulphate	3.71	4.44	0.82	0.29	3.31	3.01	1.84
Lithium sulphate			Trace	Trace	0.02	0.01	0.01
Magnesium sulphate		5.18	3.15	2.65	9.22	5.37	8.21
Potassium sulphate	0.13	1.31	0.82	0.25	0.27	0.30	0.33
Aluminium sulphate		25.88	11.20	6.88	81.05	26.11	27.85
Manganese sulphate			0.12	0.30	1.02	0.57	0.53
Iron sulphate		18.54	1.43	1.84			
Iron protosulphate			0.30	0.23	0.52	0.22	0.32
Iron persulphate					5.17	2.43	2.87
Nickel sulphate			0.10	0.13	0.46	0.26	0.41
Cobalt sulphate			0.08	0.09	0.32	0.31	0.31
Copper sulphate			0.12	0.11	6.08	2.33	3.10
Zinc sulphate			0.07	0.08	0.61	0.22	0.28
Cadmium sulphate			Trace	Trace	0.06	Trace	0.01
Calcium phosphate	0.02		Trace	Trace	0.01	0.01	Trace
Iron phosphate		0.25					
Sodium silicate		2.51					
Ammonium crenate		0.58					
Iron crenate		0.68					
Sodium chloride	0.11	0.78	0.01	0.01	0.08	0.06	0.04
Calcium fluoride			Trace	Trace	Trace	Trace	Trace
Sodium iodide	0.01	0.70					
Alumina	0.05						
Silica	0.72		2.00	2.80	3.03	3.30	3.42
Sulphuric acid		23.64	2.07	2.14	4.84	7.90	5.32
Organic matter	0.09	0.58	Trace	Trace	Trace	Trace	Trace
Total	6.46	84.64	21.54	17.94	116.27	52.73	55.09
Gases.	***Cubic in.***	***Cubic in.***	***Cubic in.***	***Cubic in.***	***Cubic in.***	***Cubic in.***	***Cubic in.***
Carbonic acid	5.60	6.16	11.22	11.39	10.38	9.91	11.06
Oxygen	1.60		1.33	1.27	1.11	1.35	1.62
Nitrogen	8.56		3.76	8.62	8.19	3.33	4.04

[a] J. W. Mallet (1878).

[b] William E. A. Alken (1878).

Analyses of mineral springs in Virginia—Continued.

Constituents.	Jordan's White Sulphur Springs.	Kimberling Springs, red sulphur Spring.	Massanetta Mineral Springs.	Pulaski Alum Springs.	Rawley Springs, main fountain.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per imp. gallon.*[e]
Sodium carbonate		6.21	1.13		
Calcium carbonate		0.72	14.78		
Magnesium carbonate	2.88	1.62	6.95		
Potassium carbonate	9.71	0.75			
Manganese carbonate	0.01		0.05		
Iron carbonate	Trace		0.38		
Calcium sulphate	5.13	2.32	0.42	1.58	
Magnesium sulphate				1.87	
Potassium sulphate	2.09		0.11	[f]0.83	
Aluminium sulphate				21.59	
Iron sulphate				108.75	
Soluble silicates				0.84	
Sodium chloride	0.76	0.42		0.56	
Potassium chloride			0.16		
Ammonium chloride			0.01		
Soda					0.31
Magnesia					0.39
Potash					0.07
Lime					0.35
Lithia			Trace		Trace
Ammonia					Trace
Iron		Trace			
Iron peroxide					1.32
Manganese protoxide					0.01
Arsenious oxide			Trace		
Alumina	0.01		0.16		0.05
Silica	0.25	0.67	0.18		0.82
Chlorine					0.03
Phosphoric acid			Trace		
Sulphuric acid		0.17		1.94	0.52
Sulphureted hydrogen	0.79				
Carbonic acid (combined)					1.56
Organic matter		2.16	0.48		0.35
Total	21.63	15.04	25.76	137.96	5.78
Gases.					*Cubic inches.*
Carbonic acid			2.64		7.24
Oxygen			8.44		2.07
Nitrogen					4.18
Carbureted hydrogen			2.25		

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[a] Thos. Antisell, analyst (1871).
[b] D. K. Tuttle, analyst.
[c] J. W. Mallet, analyst.
[d] J. L. Campbell, analyst (1870).
[e] J. W. Mallet, analyst (1878).
[f] With soda.

Analyses of mineral springs in Virginia—Continued.

Constituents.	Orkney Springs.			Rockbridge Alum Springs.		
	Healing Spring.	Powder Spring.	Bear Wallow Spring.	Chalybeate Spring.	Spring No. 1.	
	Grains per imp. gall.[a]	*Grains per imp. gall.*[a]	*Grains per imp. gall.*[a]	*Grains per gall.*[b]	*Grains per gall.*[c]	*Grains per gall.*[d]
Sodium carbonate	0.02	3.91				
Calcium carbonate	9.93	4.59				
Magnesium carbonate	1.36	3.54		0.89		
Lithium carbonate	Trace	Trace		Trace		
Manganese carbonate	Trace	0.02		0.05		
Iron carbonate	0.56	0.26		0.85		
Sodium sulphate						0.02
Calcium sulphate	1.38	0.11	0.86	4.46	1.44	1.73
Lithium sulphate			0.07			0.02
Magnesium sulphate			2.94		1.08	0.89
Potassium sulphate	0.23	0.19	0.25	0.16		0.17
Strontium sulphate		Trace				
Barium sulphate		Trace				
Aluminium sulphate	0.03	0.02	0.06			31.25
Manganese sulphate			0.02			0.86
Iron sulphate			5.45			
Iron persulphate						1.02
Nickel sulphate						0.06
Cobalt sulphate						0.03
Copper sulphate		Trace	Trace			
Zinc sulphate						0.12
Lead sulphate					Trace	Trace
Ammonium nitrate						Trace
Calcium phosphate	0.01	Trace	0.01	0.02		0.03
Sodium silicate					2.55	
Ammonium crenate					1.40	
Sodium sulphide		0.53				
Sodium chloride	0.15	0.43	0.11	0.14	0.42	0.08
Potassium chloride	0.04	0.03	0.08			
Ammonium chloride		Trace	Trace			
Calcium fluoride	Trace					Trace
Sodium iodide			Trace			
Antimony						Trace
Copper				Trace		0.04
Iron protoxide					3.68	
Iron						
Arsenic		Trace	Trace	Trace		Trace
Aluminia				0.06	14.76	
Silica	1.00	1.66	1.85	0.87		3.54
Nitric acid				Trace		
Sulphuric acid			0.43		18.79	3.24
Carbonic acid					2.62	
Carbonic anhydride	5.39	5.60				
Organic matter		Trace	0.07	0.11		Trace
Total	20.10	20.89	12.20	7.61	46.74	43.09
Gases.	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*
Sulphureted hydrogen		5.91				
Oxygen	1.64		0.46			1.53
Nitrogen	3.05	2.85	1.52			4.19
Carbon dioxide	4.64	3.62	5.78			12.87

[a] J. W. Mallet, analyst (1875).

[b] J. W. Mallet, analyst.

[c] A. A. Hayes, analyst.

[d] M. B. Hardin, analyst (1878).

Analyses of mineral springs in Virginia—Continued.

Constituents.	Rockbridge Alum Springs.					
	Spring No. 2.		Spring No. 3.	Spring No. 4.		
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[b]	*Grains per gallon.*[d]
Sodium sulphate		0.03	0.02		0.03	0.01
Calcium sulphate	3.26	8.23	2.64	3.26	2.32	0.35
Lithium sulphate		0.02	0.02		0.03	0.02
Magnesium sulphate	1.76	5.61	6.37	4.42	7.36	1.50
Potassium sulphate	1.76	0.41	0.38		0.18	0.06
Aluminium sulphate		42.61			72.37	19.00
Manganese sulphate		0.00	0.53		1.37	0.52
Iron protosulphate						0.88
Iron persulphate		1.95	1.76		2.90	Trace
Nickel sulphate		0.14	0.24		0.23	0.05
Cobalt sulphate		0.02	0.08		0.08	0.04
Copper sulphate						Trace
Zinc sulphate		0.39	0.21		0.22	0.05
Lead sulphate		Trace	Trace		Trace	
Ammonium nitrate		Trace	Trace		Trace	Trace
Calcium phosphate		0.17	0.20		0.05	Trace
Ammonium crenate	0.70			1.22		
Sodium chloride	1.01	0.11	0.11	0.44	0.14	0.14
Calcium fluoride		Trace	Trace		Trace	Trace
Antimony		Trace	Trace		Trace	
Copper		0.04	0.09		0.10	
Iron oxide	4.86			4.69		
Arsenic		Trace	Trace		Trace	
Alumina	17.91		43.95	24.09		
Silica	2.84	3.70	3.18	1.71	4.38	1.93
Sulphuric acid	15.22	3.83	2.04	5.51	3.07	2.54
Carbonic acid	7.36			4.20		
Organic matter		Trace	Trace	1.02	Trace	Trace
Total	56.68	62.85	61.77	50.56	94.83	27.09
Gases.	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*
Oxygen		1.49	1.65		4.12	
Nitrogen		3.98	4.10		1.64	
Carbon dioxide		10.89	11.95		12.72	

Constituents.	Rockbridge Alum Springs.				
	Spring No. 5.	Spring No. 6.	Spring No. 7.	Spring No. 8.	Spring No. 9.
Solids.	*Grains per gallon.*[e]	*Grains per gallon.*[e]	*Grains per gallon.*[e]	*Grains per gallon.*[e]	*Grains per gallon.*[f]
Sodium sulphate	0.24	0.18	0.23	0.32	0.24
Calcium sulphate	0.32	0.29	3.31	8.02	1.84
Lithium sulphate	Trace	0.01	0.02	0.01	0.01
Magnesium sulphate	3.15	2.65	9.22	5.36	8.21
Potassium sulphate	0.32	0.25	0.27	0.30	0.33
Aluminium sulphate	11.20	6.88	81.05	26.11	27.85
Manganese sulphate	0.13	0.31	1.03	0.57	0.53
Iron protosulphate	0.29	0.23	0.52	0.23	0.32
Iron persulphate	1.43	1.84	5.17	2.43	2.87
Nickel sulphate	0.10	0.12	0.46	0.26	0.41
Cobalt sulphate	0.08	0.09	0.31	0.31	0.31
Copper sulphate	0.12	0.11	6.08	2.33	3.10
Zinc sulphate	0.07	0.03	0.61	0.21	0.28
Cadmium sulphate	Trace	Trace	0.03	Trace	Trace
Calcium phosphate	Trace	Trace	0.01	0.01	0.01
Sodium chloride	0.01	0.01	0.08	0.06	0.04
Calcium fluoride	Trace	Trace	Trace	Trace.	Trace
Silica	2.00	2.80	3.03	3.30	3.42
Sulphuric acid	2.07	2.14	4.84	7.90	5.32
Organic matter	Trace	Trace	Trace	Trace	Trace
Total	21.53	17.94	116.27	52.73	55.09
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Oxygen	1.33	1.27	1.11	1.35	1.62
Nitrogen	3.76	3.62	3.19	3.33	4.04
Carbon dioxide	11.22	11.30	10.38	9.91	11.08
Marsh gas				Trace	

[a] A. A. Hayes, analyst.
[b] M. B. Hardin, analyst (1873).
[c] A. A. Hayes, analyst (1852).
[d] M. B. Hardin, analyst (1872).
[e] J. W. Mallet, analyst.
[f] J. W. Mallet, analyst (1873.)

Analyses of mineral springs in Virginia—Continued.

Constituents.	Stribling or Augusta Springs.			
	No. 2 Sulphur Spring.	No. 1 Chalybeate Spring.	Sulphur Spring.	Alum Spring.
	Grains per gallon.[a]	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]
Sodium carbonate	6.24	0.76	1.20	
Calcium carbonate	9.63	1.50	5.52	
Magnesium carbonate	2.01	0.98	3.87	
Potassium carbonate	0.74	0.35		
Iron carbonate	0.13	0.07		
Sodium sulphate			0.81	
Calcium sulphate	1.25	0.22		6.88
Magnesium sulphate				3.37
Potassium sulphate			0.44	1.32
Aluminium bisulphate				16.68
Iron sulphate				12.13
Calcium phosphate			Trace	
Sodium silicate			0.25	
Ammonium crenate				0.63
Sodium chloride	0.64		0.61	0.64
Silica	0.64	1.83		1.55
Sulphuric acid				9.09
Carbonic acid			3.90	3.57
Organic matter			1.23	
Total	21.28	5.21	17.83	55.86
Gases.				
Carbonic acid	10.40	24.00		
Sulphureted hydrogen	0.24		0.91	

Constituents.	Stribling or Augusta Springs.			
	No. 3 Chalybeate Spring.	No. 4 Alum Spring.	No. 5 Alum Spring.	No. 6 Alum Spring.
	Grains per gallon.[a]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[a]
Sodium carbonate	0.99			
Calcium carbonate	0.83			
Magnesium carbonate	1.10			
Potassium carbonate	0.76			
Iron carbonate	0.11			
Sodium sulphate		0.66	2.35	1.79
Calcium sulphate	3.09	14.65	16.95	19.11
Magnesium sulphate		0.53	0.34	6.57
Potassium sulphate		0.54	0.90	1.01
Aluminium sulphate		16.69	17.95	38.41
Iron sulphate		9.54	13.14	12.92
Silica	0.91	1.95	2.11	2.11
Sulphuric acid		5.03	9.82	6.54
Organic matter		3.75		
Total	7.79	53.36	63.56	88.46
Gas.	*Cubic inches.*			
Carbonic acid	16.00			

[a] D. K. Tuttle, analyst (1859).

[b] J. L. Campbell, analyst.

Analyses of mineral springs in Virginia—Continued.

Constituents.	Rock Enon Springs.	Roanoke Red Sulphur Springs.	Seven Springs, Abingdon.	Shenandoah Alum Springs.	Sweet Chalybeate Springs: Red Spring.		Variety Springs: Alum Spring.
	Grains per gall.[a]	*Grains per gall.*[b]	*Parts in* 100.[c]	*Grains per imp. gall.*[d]	*Grains per gall.*[e]	*Grains per gall.*[f]	*Grains per gall.*[g]
Sodium carbonate	1.21						
Calcium carbonate	5.13	6.53			2.70	16.00	
Magnesium carbonate		5.84				12.00	
Lithium carbonate		0.02					
Manganese carbonate		0.02					
Iron carbonate		0.06				8.00	
Copper carbonate		Trace					
Sodium sulphate		3.04	0.23		3.23		
Calcium sulphate	3.56	2.19	17.54		32.88		13.33
Lithium sulphate			0.02				
Magnesium sulphate	12.89		16.00		7.18	4.00	11.64
Potassium sulphate		0.33	0.06				0.29
Strontium sulphate		1.71	Trace				
Barium sulphate		Trace					
Aluminium sulphate			15.22				34.41
Ammonium sulphate			0.02				
Manganese sulphate			0.26				
Iron protosulphate			0.41				5.11
Iron persulphate			4.63				
Nickel sulphate			0.16				
Cobalt sulphate			0.01				
Copper sulphate			0.01				
Zinc sulphate			0.30				
Lead sulphate		Trace					
Sodium hyposulphite		0.03					
Ammonium nitrate		0.05					
Calcium phosphate		0.03	Trace				
Sodium chloride		0.24	0.33		0.09	2.00	0.29
Magnesium chloride	1.12				1.57		
Calcium chloride					0.02		
Ammonium chloride		0.02					
Calcium fluoride			Trace				
Iron (combined)						4.00	
Iron oxide or protoxide	14.25			5.22			
Iron sesquioxide					0.73		
Manganese protoxide	1.05						
Arsenic		Trace					
Alumina	0.80	0.01		12.39			
Silica	0.42	0.84	1.50			4.00	1.13
Sulphuric acid				59.54			1.37
Organic matter		0.76	0.12				
Water			42.94				
Total	40.48	21.71	99.76	77.15	48.40	50.00	67.57
Gases.	*Cub. ins. in* 100.	*Cub. ins. per gall.*	*Cub. ins. in* 100.	*Cub. ins. in* 100.	*Cub. ins. in* 100.	*Cub. ins. in* 100.	*Cub. ins. in* 100.
Carbonic acid		12.40			46.10		
Sulphureted hydrogen		2.44			Trace		
Oxygen					0.20		
Nitrogen					2.57		

[a] Gale and Mew, analysts.
[b] M. B. Hardin, analyst (1875).
[c] J. W. Mallet, analyst (1875).
[d] J. W. Mallet, analyst (1873).
[e] W. B. Rogers, analyst.
[f] Rowelle, analyst.
[g] William Gilham, analyst (1859).

Analyses of mineral springs in Virginia—Continued.

Constituents.	Wallawhatoola Alum Springs.		Warm Sulphur Springs.		Wolf Trap Lithia Springs.	Yellow Sulphur Springs.	Wayland Spring.
	Grains per gall.[a]	*Grains per gall.*[b]	*Grains per gall.*[c]	*Grains per gall.*[d]	*Grains per gall.*[e]	*Grains per gall.*[f]	*Grains per gall.*[g]
Sodium carbonate					0.24		
Calcium carbonate			4.29	5.22	7.41	8.64	
Calcium bicarbonate							3.04
Magnesium carbonate					5.09	1.38	
Magnesium bicarbonate							1.05
Lithium carbonate					0.02		
Strontium carbonate					0.39		
Ammonium carbonate					Trace		
Barium carbonate					Trace		
Manganese carbonate					0.01		
Iron carbonate					0.06	0.62	
Iron bicarbonate							0.91
Zinc carbonate					Trace		
Copper carbonate					Trace		
Calcium sulphate	13.27	7.538	5.47	14.53		63.30	
Aluminium sulphate	72.10	137.889				3.18	
Magnesium sulphate	2.31	15.434	9.98			21.10	
Lithium sulphate		0.128					
Maganese sulphate		1.245					
Potassium sulphate	2.09			1.88	0.06	0.10	
Potassium and aluminium sulphate.		4.201					
Sodium and aluminium sulphate.		3.867					
Sodium sulphate	2.12				0.06	0.75	
Ammonium sulphate				0.86			
Iron protosulphate	5.39	0.489					
Iron persulphate		23.741					
Sodium nitrate					2.63		
Calcium phosphate		0.055				0.01	
Magnesium phosphate						Trace	
Aluminium phosphate					0.04		
Magnesium biborate					Trace		
Sodium silicate	2.04			} 1.72			
Magnesium silicate				}			
Iron crenate				2.50			
Sodium chloride	0.39	0.710			2.63	0.07	
Calcium chloride			3.97				
Potassium chloride						0.10	
Calcium fluoride					Trace		
Sodium bromide					[h]0.01		
Soda			Trace				
Lithia	Trace	Trace					
Titanic oxide					Trace		
Iron oxide or protoxide		20.040				Trace	
Silica		4.111			2.02		
Sulphuric acid	33.82						
Carbonic acid				6.92			
Organic matter	1.75	Trace			Trace	3.78	
Total	135.28	199.408	23.71	32.63	20.67	104.98	5.00
Gases.	*Cub. ins. in* 100.	*Cub. ins. in* 100.	*Cub. ins. in* 100.	*Cub. ins. in* 100.	*Cub. ins. in* 100	*Cub. ins. in* 100.	*Cub. ins. in* 100.
Carbonic acid	In excess			1.02			
Sulphureted hydrogen			0.19	0.25			
Oxygen					1.70		
Nitrogen			1.62	3.25	3.60		
Carbon dioxide			2.64		12.38	10.00	

[a] J. L. Campbell, analyst (1879).
[b] C. F. Chandler, analyst (1884).
[c] W. B. Rogers, analyst (1835).
[d] A. A. Hayes, analyst (1852).
[e] M. B. Hardin, analyst (1880).
[f] William Gilham, analyst.
[g] W. S. C. Taylor, analyst (1883).
[h] With iodide.

WEST VIRGINIA.

West Virginia is noted for its mineral springs. Berkeley Springs is one of the oldest resorts in the United States, the town of Bath, named after the English watering place, having been laid out in 1777, while Greenbrier White Sulphur Springs, which are so well known throughout the country, have been used medicinally since 1778 or 1779. The best known springs are in the eastern and southeastern portions of the State, especially in the Alleghany Mountains. The western counties also have a number of important springs and mineral wells, and when the central part of the State becomes better known many springs will probably be added to the list. The general characters of the waters are like those of Virginia. The springs are thermal and cold, saline, chalybeate, carbonated, sulphureted, and acid. The saline and sulphureted waters predominate.

Mineral springs of West Virginia.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Alum Spring, 1 mile from Little Sewell Mountain, Greenbrier County.	....	......	....	....	Unimproved.
Aurora Highlands Spring, Aurora, Preston County.	1	75	48	....	Improved.
Barger's Springs, Barger's Springs, Summers County.	2	20	... .	....	Local resort.
Berkeley Springs, Berkeley Springs, Morgan County.	5	3,000	75	Calcic	Resort.
Blue Sulphur Springs, Blue Sulphur Springs, Greenbrier County.	2	2,000	46	Sulphureted ..	Resort prior to the war.
Bluish-White Sulphur Spring, Edray, Pocahontas County.	1	4	....	....do	Unimproved.
Borland Mineral Well, Borland[a], Pleasants County.	......	......	....	Alkaline, saline, sulphureted.	Local resort.
Capon Springs, Capon Springs, Hampshire County	......	....	54 to 66	Alkaline, carbonated.	Used commercially and as a resort.
Chalybeate springs:					
Near Fayette Station, Fayette County.	......	.... ..	....	....	Unimportant and unimproved.
Near Edray, Pocahontas County.	1	....	....	....	Unimproved.
Near Brandywine, Pendleton Co.	3	... .	....	Chalybeate	Do.
Columbia Sulphur Spring, Columbia Sulphur Springs, Greenbrier County.	1	10	....	....	Used to small extent as a resort.
Crimson Springs, Crimson Springs, Monroe County.	....	....	....	....	Unimproved; used locally for medicinal purposes.
Floding Springs (Blue Sulphur Springs), Floding Springs, Cabell County.	2	.... ..	....	Sulphureted ...	Resort.
Greenbrier White Sulphur Springs, White Sulphur Springs, Greenbrier County.	2	1,860+	62	Calcic, sulphureted, and chalybeate.	Used commercially and as a resort.
Green Sulphur Springs, Green Sulphur Springs, Summers County.	3	......	....	Sulphureted, &c.	Unimproved.
Grey Sulphur Springs, Peterstown, Monroe County.	2	.... ..	56	Saline, sulphureted.	Unimportant now, but used as a resort prior to 1840.
Guinn's Spring, near mouth of Lick Creek, Fayette County.	......	.. ...	....	Sulphureted ...	
Hardy White Sulphur Springs, 14 miles south of Moorefield, Hardy County.	.....	65	48 to 50	.. do	

[a] This locality is taken from Walton.

Mineral springs of West Virginia—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks
Hart Well, near Willow Island, Pleasants County.	.....	......	......	Alkaline, saline.	Resort.
Howard's Lick, Howard's Lick, Hardy County.	.....	......	....	....	
Humphrey's Spring, between Salt Sulphur and Red Sulphur Springs, Monroe County.	.....	......	50 to 60	....	
Irondale Spring, Irondale Furnace, Independence, Preston County.	1	180	45	Calcic, saline ...	Used commercially.
Kanawha Saline Spring, Kanawha Valley.	.....	......	....	Saline	
Magnesia Spring, near White Sulphur Springs, Greenbrier County.	.....	......	....	Calcic, saline ...	
Mechem's Spring, 2 miles from Berkeley Springs, Morgan County.	.....	......	....	....	
Mineral Springs, near Clarksburg, Harrison County.	.....	......	....	....	
Mineral Well, Millbourne Ridge, near Muse's Bottom, Jackson County.	1	......	....	....	
Orrick's Sulphur Spring, 4 miles from Berkeley Springs, Morgan County.	.....	......	58	Sulphureted	
Parkersburg Mineral Wells, 6 miles south of Parkersburg, Mineral Wells, Wood County.	10	40	46	Saline, carbonated.	Used commercially and as a resort.
Red Sulphur Springs, Red Sulphur Springs, Monroe County.	2	210	51	Sulphureted ...	Do.
Salt Sulphur Springs, Salt Sulphur Springs, Monroe County.	4	400+	49 to 65½	....do	Do.
Shannondale Springs, 5½ miles from Charlestown, Jefferson County.	3	......	55	Saline, chalybeate.	Resort.
Sharpnack's Well (650 feet), Petroleum, Ritchie County.	1	500	....	....	Used to some extent as a resort.
Spa Spring, 1½ miles from Berkeley Springs, Morgan County.	.....	......	53	Chalybeate	
Sulphur springs:					
Near Blue Sulphur Springs, Greenbrier County	8	......	....	....	Unimproved.
Sweet Springs, Sweet Springs, Monroe County.	1+	48,000	79	Calcic	Resort.
Webster Salt Sulphur Springs, Webster Court-House, Webster County.	2	......	....	Saline, sulphureted.	Used to some extent as a resort.

Analyses of mineral springs in West Virginia.

Constituents.	Berkeley Springs.	Blue Sulphur Springs.	Borland Mineral Well.	Capon Springs.	
				Main Spring.	Beauty Spring.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*	*Grains per gallon.*[b]	*Grains per imp. gallon.*[c]	*Grains per imp. gallon.*[c]
Sodium carbonate			77.80	0.59	0.63
Calcium carbonate	5.00	5.05	8.75	8.33	8.36
Magnesium carbonate		0.94	1.86	1.44	1.27
Lithium carbonate				Trace	Trace
Manganese carbonate				Trace	Trace
Iron carbonate			0.64	0.04	0.05
Aluminium carbonate					
Copper carbonate					Trace
Sodium sulphate		16.22	37.87		
Calcium sulphate		46.55		0.59	0.41
Magnesium sulphate	0.36	6.38			
Potassium sulphate			22.63	0.17	0.16
Strontium sulphate				Trace	Trace
Nitrates				Trace	Trace
Calcium phosphate				Trace	Trace
Aluminium phosphate			0.23		
Earthy phosphates		Trace.			
Calcium silicate	0.64				
Calcium crenate	3.64				
Iron crenate	0.08				
Sodium chloride	0.89	4.21	240.07	0.06	0.05
Calcium chloride	0.21	0.01			Trace
Magnesium chloride			2.14		
Calcium fluoride				Trace	Trace
Magnesium bromide			0.28		
Magnesium iodide			0.02		
Iron protoxide		0.08			
Manganese			Trace		
Alumina				0.02	0.02
Silica			0.59	0.70	0.67
Iodine		Trace			
Organic matter		6.93	Trace	0.20	0.19
Loss	0.06				
Total	10.88	86.32	392.87	12.14	11.81
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	19.00	6.35		8.56	7.76
Sulphureted hydrogen		1.03			
Oxygen	16.60	1.29		1.76	1.68
Nitrogen	64.30	7.49		3.68	3.68
Total	19.90	16.16		14.00	13.12

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[a] A. A. Hayes, analyst (1853).

[b] T. G. Wormley, analyst.

[c] J. W. Mallett, analyst.

Analyses of mineral springs in West Virginia—Continued.

Constituents.	Grey Sulphur Springs.			Greenbrier White Sulphur Springs.		
	Aperient Spring.	Anti-dyspeptic Spring.		Name unknown.	Name unknown.	Sour Spring.
Solids.	*Grains in* 100 *cu. in.*[a]	*Grains in* 100 *cu. in.*[a]	*Parts in* 100.+[b]	*Grains per gall.*[c]	*Grains per gall.*[a]	*Grains in* 100 *cu. in.*[a]
Sodium carbonate	1.75	2.46	50.00			
Calcium carbonate	2.07	2.84	38.90	7.07	3.53	
Magnesium carbonate	2.46	1.68	8.10		1.17	
Ammonium carbonate	Trace	Trace				
Sodium sulphate	0.36	0.43			9.35	
Calcium sulphate			Trace	78.35	73.19	
Magnesium sulphate			Trace	35.42	19.03	
Aluminium sulphate					0.02	
Iron protosulphate					0.15	
Earthy phosphates					Trace	
Silicates				3.46		
Sodium chloride	0.34	0.21	Trace		0.52	
Calcium chloride					0.02	
Magnesium chloride				1.00	0.16	
Potassium chloride	Trace	Trace				
Magnesia						Trace
Lime						5.65
Iron oxide			Trace			
Iron protoxide						12.12
Iron peroxide	0.09	0.05				
Alumina						16.20
Silica	0.75	0.32	3.60			
Iodine					([d])	
Sulphuric acid						48.83
Organic matter	Large am't	Large am't		4.36	0.01	
Total	7.82	7.99	[e]100.60	129.66	107.15	82.80
Gases.	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*	*Cub. inches.*
Carbonic acid	6,18	6.54		11.28	8.48	
Sulphureted hydrogen	0.41	0.20		0.24	2.96	
Oxygen	0.40	0.40		0.48	0.40	
Nitrogen	3.00	3.07		4.64	4.32	
Total				16.64	16.16	

[a] W. B. Rogers, analyst.

[b] C. U. Shepard, analyst (1835).

[c] A. A. Hayes, analyst (1842).

[d] Undetermined.

[e] There are 22.15 grains per gallon.

Analyses of mineral springs in West Virginia—Continued.

Constituents.	Hart Well.	Howard's Lick.	Humphrey's Spring.	Irondale Spring.	Magnesia Spring, near White Sulphur Springs.	Parkersburg Mineral Wells.
Solids.	*Grains per gall.*[a]	*Grains in 200 cu. in.*[b]	*Grains in 100 cu. in.*[b]	*Grains per gall.*[c]	*Grains per imp. gall.*[d]	*Grains per gall.*[e]
Sodium carbonate	78.86	5.33				4.00
Calcium carbonate	8.86	0.44	6.38		22.37	
Magnesium carbonate	1.88	0.20	1.01		11.16	
Iron carbonate	[f]0.70				0.32	
Sodium sulphate	38.38	0.19	15.54		1.20	24.00
Calcium sulphate			8.73	60.42	21.01	
Magnesium sulphate			4.23	4.34	12.06	10.00
Potassium sulphate	22.92			6.76	1.46	
Aluminium sulphate				11.34		
Ammonium sulphate					0.18	
Manganese sulphate				2.86		
Iron sulphate				[f]Trace		4.00
Aluminium phosphate	0.23					
Sodium chloride	243.59	0.46	2.73	1.36	1.26	41.00
Magnesium chloride	2.16		1.61			
Potassium chloride					1.74	
Magnesium bromide	0.28					
Magnesium iodide	0.02					
Lithia					Trace	
Iron protoxide			Trace			
Iron peroxide		0.12			0.43	
Manganese	0.07					
Silica	0.58	0.37		1.44	0.86	
Iodine			[g]Trace	[g]Trace	Trace	1.00
Bromine					Trace	
Sulphuric acid						
Organic matter	Trace	Trace	[h]Much		Trace	
Vegetable and volatile substances				8.24		
Total	398.53	7.11	40.23	96.76	74.05	84.00
Gas.						
Carbonic acid						16.00

Constituents.	Salt Sulphur Springs.		Shannondale Springs.	Sweet Springs.	Red Sulphur Springs.
	Old Spring.	Iodine Spring.			
Solids.	*Grains per gallon.*[b]	*Grains per gallon.*[i]	*Grains in 100 grains of solid contents.*[j]	*Grains per gallon.*[b]	*Grains per gallon.*[k]
Sodium carbonate		10.80			
Calcium carbonate	10.26	33.00	10.5	30.06	5.25
Magnesium carbonate	3.31	7.00		0.82	4.81
Potassium carbonate		2.33			
Iron carbonate			0.7		
Sodium sulphate	22.36	24.00		6.34	4.14
Calcium sulphate	84.90	68.00	63.0	13.17	0.55
Magnesium sulphate	18.21	20.00	23.5	9.39	
Iron sulphate			0.3		
Earthy phosphates	Trace	0.73		Trace	0.82
Sodium chloride	1.58	1.50	1.0	0.14	
Calcium chloride	0.06	0.56		0.14	
Magnesium chloride	0.26	0.28	1.0	0.31	
Iron peroxide	0.10	1.06		0.14	
Alumina		0.18			
Silica		1.76		0.17	
Iodine	Trace	0.63		Trace	
Bromine		0.65			
Organic matter	9.24				[h]8.39
Total	150.28	172.48	100.0	60.68	23.96
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	13.28	34.56	Undetermined	88.00	8.00
Sulphureted hydrogen	3.44	19.12	Undetermined		1.04

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[a] S. C. Wells, analyst.
[b] W. B. Rogers, analyst.
[c] Prof. Breneman, analyst.
[d] Wm. E. A. Aiken, analyst.
[e] S. F. Berny, analyst.
[f] With cobalt and nitric acid.
[g] With sodium.
[h] With sulphur.
[i] D. Stewart, analyst.
[j] DeButts, analyst.
[k] A. A. Hayes, analyst (1842).

NORTH CAROLINA.

North Carolina enjoys the distinction of being one of the two States on the Atlantic coast that possess hot springs. Usually her mineral springs are not different from those occurring along the coast and in the region of the Appalachians in the neighboring States. As in Virginia, chalybeate and sulphureted springs are most numerous. The books usually credit the State with four or five localities. The present list includes 66, of which a fair proportion are utilized as places of resort, while many have well-established local reputations. Seven of the springs are used commercially. Analyses are given of 18 springs.

For a considerable number of these thanks are due to Prof. Charles W. Dabney, jr., of the State agricultural experiment station. Others are taken from Professor Kerr's report on the geology of North Carolina. The greatest part of the information as to the spring localities has been derived from direct correspondence with the spring-owners.

Mineral springs of North Carolina.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
All Healing Springs, All Healing, Gaston County.	12	3,800+	52 to 58	Chalybeate, sulphureted.	Resort.
Alum Spring, near Catharine Lake, Onslow County.	1	90,000	62	Chalybeate, sulphur.	Do.
Alum Spring, Bald Mountain, near Chimney Rock, Rutherford County.					Has local reputation.
Bell Spring, Palmerville, Stanly Co	1				Local resort.
Blackwell's White Sulphur Springs, 4 miles from Alexander, Buncombe County.	4	50+		Sulphureted	Resort.
Burke's Chalybeate Springs, near Taylorsville, Alexander County.					Unimproved.
Chalybeate Mineral Spring, near Varina, Wake County.	1	15			Do.
Chalybeate springs:					
Near Marion, McDowell County					
Five miles south of Wadesborough, Anson County.					
West of Sandford, Moore County					
One and a half miles west of Ellerbe Springs, Richmond County.			60		
Near Laurinburg, Richmond Co			62		
Near Shelby, Cleveland County					
Charlotte Mineral Spring, Charlotte, Mecklenburg County.					
Chatham Mineral Spring, near Pittsborough, Chatham County.				Saline	
Cleveland Mineral Springs, near Shelby, Cleveland County.	3	180	58	Sulphureted, chalybeate, &c.	Resort.
Cowhead Spring, 4 miles north of Washington, Beaufort County.			60	Chalybeate	Do.
Creswell's Sulphur Spring, 2 miles from Mooresville, Iredell County.	1	9		Sulphureted	Do.
Dennison's Mineral Well, New Berne, Craven County.	1		60		
De Hart's Springs, near Nantahalah, Swain County.					

Mineral springs of North Carolina—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Ellendale Chalybeate Springs, Ellendale, west of Taylorsville, Alexander County.					To be used commercially in future.
Ellerbe Spring, Ellerbe Springs, Richmond County.	1	60	60		Local resort.
Eupeptic Spring, 15 miles north of Statesville, Iredell County.	1	9		Sulphureted	Once a considerable resort.
Ewing Springs, Sulphur Springs, Montgomery County.			65		
Glen Alpine Spring, 10 miles south of Morganton, Burke County.				Saline, carbonated.	
Haywood White Sulphur Springs, Waynesville, Haywood County.					Resort.
Healing Springs, Healing Springs, Davidson County.	2	120			Local resort.
Henderson Mineral Springs, 1 mile from Henderson, Vance County.	2	45	50	Chalybeate	Do.
Henson's White Sulphur Spring, near Island Ford, Rutherford County.	1			Sulphureted	Resort to limited extent.
Jackson Springs, Jackson Springs, Moore County.	2	80	61	Chalybeate	Resort.
Jones' White Sulphur and Chalybeate Springs, 10 miles south of Ridgeway and 11 miles from Warrenton, Warren County.	2				Was once a resort.
Kittrell Springs, Kittrell, Vance County.				Chalybeate	
Lawrence's Chalybeate Spring, Murfreesborough, Hertford County.				do	Unimproved.
Lemon Springs, Lemon Springs, 2 miles west of Munn's Station, Moore County.	2		59	Chalybeate, &c.	Water is sold to some extent and the place is a small resort.
Leinster or Poison Springs, 5 miles south of Statesville, Iredell County.	7				Used commercially and as a resort.
Lewis Spring, near Green Hill, Rutherford County.					Has local reputation.
Loudermilk Sulphur Spring, 5 miles west of Taylorsville, Alexander County.					Once a resort; unimproved at present.
Manganus Springs, 1½ miles north of Chapel Hill, Orange County.	2			Sulphureted and chalybeate.	
McBride's Springs, near Shelby, Cleveland County.					
Millstead's All Healing Mineral Spring, near Ellendale, Alexander County.	1	120	56		Resort.
Mineral springs:					
At Ansonville, Anson County					
Ten miles southwest of Wadesborough, Anson County.			60		
At Haw River, Alamance County.				Lithia	
At Icard Station, Burke County					
Seven miles northeast of Asheville, Buncombe County.					
Near Rock Spring, Orange County	2				
At Greensborough, Guilford Co					
Mineral Well, Thomasville, Davidson County.					
Misenheimer's Sulphur Springs, near Copal Grove, Stanly County.	2	10+		Sulphureted and chalybeate.	Do.
Misheman's Springs, near Bilesville, Stanly County.				Chalybeate	
Mount Vernon Mineral Springs, Mount Vernon Springs, Chatham County.	2				Used commercially to small extent and as a resort.
Panacea Springs, Panacea Springs, Halifax County.	13	3,700	58 to 60	Saline, carbonated, and chalybeate.	Used commercially and as a resort.
Park's Alkaline Mineral Spring, 6 miles east of Pelham, Caswell County.	1	50	56	Calcic	Used commercially and as a local resort.

***Mineral springs of North Carolina*—Continued.**

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Patterson Springs, near Shelby, Cleveland County.	......	....	....	....	
Piedmont Springs, near Danbury, Stokes County.	2	....	65	Chalybeate	Resort.
Piedmont Springs, Piedmont Springs, Burke County.	2	....	....	Sulphureted and chalybeate.	Do.
Rocky River Springs, near Silver, Stanly County.	9	400	56	....	Do.
Seven Springs, Seven Springs, Wayne County.	7	433	....	Chalybeate, &c.	Used commercially and as a resort.
Shaw's Healing Springs, ½ mile north of Littleton, Halifax County.	16	....	....	....	Resort.
Shocco Springs, 5 miles from Warrenton, Warren County.	......	....	....	....	Do.
Sparkling Catawba Springs, Sparkling Catawba Springs, 6 miles from Hickory, Catawba County.	5	60	59	Saline, carbonated.	Used commercially to some extent and as a resort.
Stonewall Springs, 6 miles from Graham, Alamance County.	......	....	....	....	
Strader's Mineral Spring, 3 miles north of Pelham, Caswell County.	......	....	....	Chalybeate	Unimproved.
Sue Spring, near Warrenton, Warren County.	......	....	....	Sulphureted (?).	
Sulphur and Chalybeate Springs, on French Broad River, Madison County.	......	....	....	....	
Sulphur Springs, Sulphur Springs, Montgomery County.	2	20	40	Sulphureted ...	Resort.
Sulphur springs:					
Near Petra Mills, Caldwell Co ...	......	....	....	....	
Near Settle, Iredell County	1+	....	48	Sulphureted and chalybeate.	Local resort.
Five and one-half miles southwest of Asheville, Buncombe County.	......	....	....	....	Resort.
Ten miles northwest of Asheville, Buncombe County.	......	....	....	....	Do.
Warm Springs, Warm Springs, Madison County.	20	....	92 to 117	....	Do.
Warren White Sulphur Springs, 10 miles from Ridgeway, Warren County.	......	......	....	....	
White sulphur springs:					
At Catawba, Catawba County ..	......	....	....	....	
Six miles east of Taylorsville, Alexander County.	1	50	....	Sulphureted ...	Used as a resort to some extent.
Wilson's White and Red Sulphur Springs, near Shelby, Cleveland County.	......	....	....	....	
Wise's Spring, Murfreesborough, Hertford County.	......	....	....	Chalybeate	Unimproved.
Yadkin Mineral Springs, Palmerville, Stanly County.	......	....	....	Chalybeate, sulphureted.	Do.

Analyses of mineral springs in North Carolina.

Constituents.	Alum Spring of Onslow County.	Charlotte Mineral Spring.	Chatham Mineral Spring.	Cleveland Mineral Springs. White Sulphur Spring.	Cleveland Mineral Springs. Red or Iodine Spring.
Solids.	*Grains per gallon.*[a]	*Grains per imp. gallon.*[b]	*Grains per imp. gallon.*[b]	*Grains per gallon.*	*Grains per gallon.*
Calcium carbonate				4.50	3.12
Calcium sulphate		36.00		18.70	[c]17.42
Magnesium sulphate		4.53			
Sulphates			Trace		
Nitrates			Trace		
Sodium chloride		3.30	[d]28.80		
Magnesium chloride			36.56	7.65	
Calcium chloride			39.13	4.84	
Magnesia	0.49				
Lime	4.80				
Iron		Trace			
Iron oxide	[e]3.80		Trace		
Alumina		Trace	Trace		
Silica	1.65	[f]18.97	Trace		
Chlorine	0.92				
Sulphuric acid	0.25				
Organic matter	5.16				
Total	17.07	62.80	104.49	35.69	20.54
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid				4.80	4.22
Sulphureted hydrogen					

Constituents.	Cowhead Spring.	Ellerbe Spring.	Glen Alpine Spring.	Greensborough Spring.	Spring at Icard Station.
Solids.	*Grains per gallon.*[a]	*Grains per imp. gallon.*[g]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per imp. gallon.*[b]
Calcium carbonate		3.64			
Iron carbonate					2.50
Calcium sulphate		4.56			
Sodium chloride		0.80			
Soda				0.27	
Magnesia	0.06		0.25	0.42	
Lime	1.17		1.72	1.62	
Iron oxide	[e]0.86		[e]0.92	0.60	
Alumina				0.18	
Silica	3.76		1.60	2.10	
Chlorine	0.18		0.37	0.42	
Sulphuric acid	1.23		0.74	0.12	
Carbonic acid			32.22	Large am't	
Organic matter	5.79		1.79	1.02	
Total	13.05	9.00	39.61	6.75	2.50
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid		Present			Large am't
Sulphureted hydrogen					Trace

[a] W. C. Kerr's Geology of North Carolina, Vol. 1 (1875).

[b] C. W. Dabney, jr., analyst.

[c] With iodine and magnesia.

[d] With potassium chloride.

[e] With alumina.

[f] With combined water, &c.

[g] C. W. Dabney, jr., analyst (1883).

Analyses of mineral springs in North Carolina—Continued.

Constituents	Dennison's Mineral Well.	Kittrell Springs.	Panacea Spring, near Littleton.	Park's Alkaline Mineral Spring.	Mineral Well, Thomasville.
	Grains per imp. gallon.[a]	*Grains per imp. gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[b]
Calcium carbonate	12.58			4.80	
Iron carbonate		9.20			
Sodium sulphate				1.48	
Magnesium sulphate				1.50	
Sodium chloride	4.94			Trace	
Soda			2.23		1.09
Magnesia			0.20		
Magnesium					0.75
Potassium			0.70		
Lime			1.20		1.74
Iron	4.40				
Manganese			0.01		
Iron oxide			2.18	3.50	0.14
Alumina	[d]3.48		0.32	3.50	
Silica			1.18	Trace	1.01
Sulphur				0.15	
Chlorine					2.62
Phosphoric acid			0.53		1.00
Hydrochloric acid			0.81		
Sulphuric acid			0.43		0.40
Carbonic acid					0.82
Organic matter					3.95
Total	25.40	9.20	9.79	14.93	13.52
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid		Large am't	Large am't		

Constituents.	Warm Springs.				
	Bathing Springs.	Drinking Springs.	Warm Spring.	Iron Spring.	Hot and Warm Springs.
	Grains per gallon.[e]	*Grains per gallon.*[e]	*Grains per gallon.*	*Parts in 1,000,000.*	*Grains per gallon.*[f]
Sodium carbonate			3.68		
Sodium sulphate	9.03	8.90	4.24		
Calcium sulphate	40.88	40.54			17.56
Magnesium sulphate	1.34	8.13	7.64		7.50
Potassium sulphate	0.36	0.47			
Soluble silicates	8.97	9.54			
Iron crenate			2.34		
Sodium chloride	0.91	1.10	2.46		
Magnesium chloride	0.22	0.37			5.00
Calcium chloride	10.10	8.94	11.48		
Potassium chloride	0.31	0.50			
Magnesium				7.4	
Calcium				140.8	
Iron				31.9	
Manganese				Trace	
Silica			3.82	72.1	
Sulphuric acid				32.4	
Carbonic acid				304.6	
Organic matter				38.2	
Insoluble residue					2.56
Loss					1.25
Total	72.12	78.49	35.66	627.4	33.87
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	10.96	10.72			
Sulphureted hydrogen	1.76	2.48			

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[a] C. W. Dabney, jr., analyst.

[b] W. C. Kerr, Geology of North Carolina (1875).

[c] A. R. Ledoux, analyst.

[d] With magnesia and combined oxygen.

[e] E Adelmarth, analyst.

[f] E. D. Smith, analyst.

SOUTH CAROLINA.

Chalybeate springs are said to abound in South Carolina and many of them are resorted to locally to a considerable extent. Glenn Springs and the Charleston Artesian Well are well known beyond the State limits. The latter, with several other artesian wells in the same city, is thermal, the temperature of the waters being almost high enough to class them as hot. They are said to possess medicinal properties. So far as learned, only the Glenn Springs, Garrett Spring, and Chick's Springs are at present of commercial importance. The Williamston Springs were once a favorite resort.

Mineral springs of South Carolina.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Ambler's Mineral Spring (formerly Griffin's), 7 miles from Pickens Court-House, Pickens County.	1	60	° 40 to 50		Used on a small scale as a resort.
Artesian wells:					
Citadel Green, Charleston, Charleston County.	1	15,000	99.5	Alkaline, saline.	
Commercial Cotton Press, Charleston, Charleston County.	1				
Chisolm's Mill, Charleston, Charleston County.	1				
Coosaw, Beaufort County					
Charleston Old Artesian Well, Charleston, Charleston County.			87	Alkaline, saline	
Chalybeate and sulphur springs, near the Saluda River, Laurens County.					
Cherokee Springs, 8 miles north of Spartanburg, Spartanburg County.			62	Chalybeate, &c.	Resort.
Chick's Springs, Chick's Springs, Greenville County.	5	200	60	Sulphureted, &c	Resort prior to 1861; used commercially now.
Garrett Spring, ½ mile from Spartanburg, Spartanburg County.	1	25	64	Chalybeate	Has a local reputation as a resort and is used commercially to some extent.
Glenn Springs, Glenn Springs, Spartanburg County.	2	60	00	Calcic, sulphureted.	Used commercially and as a resort.
Kirby Springs, 3 miles from Glenn Springs, Spartanburg County.					Has a local reputation.
Limestone springs, near Gaffney City, 2 miles east of Spartanburg, Spartanburg County.			61	Alkaline, carbonated.	Once used as a resort, now site of a school.
Love's Springs, 3 miles from Cowpens, Spartanburg County.					
Mineral springs:					
One-fourth mile from Taylor's Station, near Chick's Springs, Greenville County.				Chalybeate	Unimproved.
Three and one-half miles from Taylor's Station, near Chick's Springs, Greenville County.				Sulphureted	Do.
At Cowpens Furnace, near Pacolet, Spartanburg County.					
At Mineral Springs, Marion Co.				Chalybeate	Resort.
At Bennettsville, Marlborough Co.					Do.
At base of Henry's Knob, York Co.					
Seven miles from Abbeville Court House, Abbeville County.					
Near Parson's Mountain, Abbeville Court House, Abbeville Co.				Chalybeate	Unimproved.
On Saluda River, near Pinson's Ford, Abbeville County.				Saline, chalybeate.	Do.

Mineral springs of South Carolina—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Mineral Well, 2 miles west of Gaffney City, Spartanburg County.	....	....	60	....	Unimproved.
New Spring, 8 miles north of Spartanburg, Spartanburg County.	......	....	64	Sulphureted, chalybeate, &c	Has a local reputation.
Poinsett's Spring, Spartanburg County	......	....	..	....	
Reedy Springs, near Cranesville, Marion County.	3	600+	....	....	Resort.
Seneca Mineral Springs, Seneca, Oconee County.	2	....	....	Chalybeate	
West's Spring, West Springs, Union Co	....	....	65	....do	Do.
Williamston Springs, Williamston, Anderson County.	......	....	....	....	
Wilson's Springs, Spartanburg County.	......	....	....	....	

Analyses of mineral springs in South Carolina.

Constituents.	Charleston Artesian Wells.				Coosaw Artesian Well.	Glenn Springs.
	Old Artesian Well.	Citadel Green Well.	Commercial Cotton Press Well.	Chisolm's Mill Well.		
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate	....	47.26	....	30.88	30.75	....
Sodium bicarbonate	71.06	....	....	....	....	....
Calcium carbonate	....	....	26.24	....	....	....
Calcium bicarbonate	0.12	....	....	....	....	....
Magnesium carbonate	....	....	....	....	....	3.32
Magnesium bicarbonate	0.02	....	....	....	....	....
Iron carbonate	....	0.34	....	....	....	....
Sodium sulphate	....	....	....	....	2.24	....
Calcium sulphate	....	0.44	10.62	4.12	0.68	91.50
Potassium sulphate	....	....	....	19.21	....	....
Magnesium sulphate	....	0.17	13.88	2.82	1.04	....
Potassium nitrate	....	....	....	....	0.80	....
Sodium nitrate	....	0.55	....	....	....	....
Sodium chloride	63.38	11.39	....	136.88	6.29	2.21
Potassium chloride	....	....	....	....	1.94	0.52
Magnesium chloride	....	0.23	....	4.85	....	....
Sodium silicate	....	2.52	204.41	0.66	1.82	....
Alkalies, chlorides	....	....	1.98	....	....	....
Silica	Trace	0.36	....	2.34	1.20	....
Loss	....	....	....	13.17	....	....
Organic matter	Trace	1.73	....	....	1.47	....
Iron oxide	Trace	....	....	....	....	....
Carbonic acid	0.79	....	....	....	....	....
Aluminium oxide	Trace	....	....	....	....	....
Undetermined	....	....	7.35	....	....	....
Total	135.37	64.99	264.48	214.93	48.18	97.55

[a] C. U. Shepherd, jr., analyst (1868).
[b] S. T. Robinson, analyst (1879).
[c] William Robertson, analyst (1880).
[d] F. F. Chisolm, analyst (1879).
[e] C. U. Shepherd, jr., analyst (1880).

GEORGIA.

In the few general works on the mineral springs of the United States very little space is given to Georgia. Only five or six localities are usually mentioned, whereas there are at least twenty-six that are more or less improved as places of resort. Janes's Hand-Book of the State of Georgia, published in 1876, enumerates twenty-three. In the Manual of Georgia, 1878, the statement is made that the mineral springs of the State are innumerable and in variety correspond with the multifarious ores. Our list includes fifty-six, most of them chalybeate and sulphureted. The best description of Georgia mineral springs is found in the pamphlet by Dr. J. R. Duggan, published at Macon in 1881. It is confined for the most part to the improved springs and describes altogether twenty-eight. The greater part of the analyses given in the tables are derived from this pamphlet.

Mineral springs of Georgia.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks.
Angier's Mineral Springs, Atlanta, Fulton County.	3	15		Carbureted, chalybeate.	Resort.
Atlanta Mineral Spring, Atlanta, Fulton County.	1			Sulphureted, chalybeate.	Do.
Beall Spring, 8 miles south of Warrenton, Warren County.	1	60		..do	Do.
Betheeda Spring, Lumpkin County					
Bowden Lithia Springs, 17 miles from Atlanta, Fulton County.				Saline	
Camp's Spring, Atlanta, Fulton County.	1			Sulphureted, chalybeate.	Do.
Cannon's Spring, Toomsborough, Wilkinson County.	1			Chalybeate	Unimproved at present.
Catalytic Springs, ½ mile from Catalytic.[1]					
Catoosa Springs, near Ringgold, Catoosa County.	52		62	Saline, calcic, chalybeate, sulphureted, &c.	Resort and is beginning to be used commercially to some extent.
Chalybeate Springs, Chalybeate Springs, Meriwether County.	3	1,500+		Sulphureted, chalybeate.	Resort.
Claremonde Chalybeate Spring, Warthen, Washington County.	1			Carbonated, chalybeate.	
Cohutta Springs, Cohutta Springs, Murray County.	10	300		Chalybeate?	Do.
Daniel Mineral Spring, Union Point, Greene County, near Athens, Clarke County.	1	80	62		Used commercially and as a resort.
Dougherty's Springs, Polk County					
Everett's Springs, Everett's Springs, Floyd County.					
Ferrolithic Spring, Athens, Clarke County.				Chalybeate	Local resort.
Franklin Springs, near Royston, Franklin County.	3	150	60	....do	Resort.
Fullwood Springs, near Lime Branch, Polk County.	7			....do	Unimproved.
Garnet Springs, near Toccoa Falls, Toccoa, Habersham County.	1+			Saline, chalybeate.	Local resort.
Glenn's Spring, Early County					
Glen Ella Springs, Tallulah Falls, Tallulah, Rabun County.					

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[1] Taken from Pepper's list. Have been unable to verify location.

Mineral springs of Georgia—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Gordon Springs, Gordon Springs, Whitfield County.				Chalybeate	Unimproved, but once a resort.
Gower's Spring, Gainesville, Hall County.				do	Resort.
Heard's Spring, Wilkes County					Do.
Helicon Springs, Athens, Clarke County.	30			Chalybeate	Unimproved.
Indian Springs, Indian Springs, Butts County.	1	60	64	Sulphureted, saline.	Resort.
Lawrence Mineral Springs, near Menlo, Chattooga County.	10	400	60?	Chalybeate	Used locally.
Leggs Springs, near Jefferson, Jackson County.				do	Do.
Lifsey's Warm Spring, 5 miles south of Zebulon, Pike County.	1	500	74		Resort.
Madison Spring, Madison Springs, Madison County.				Chalybeate	Once used as a resort.
Magnesia Spring, Tallulah Falls, Tallulah, Rabun County.					
Magnolia Spring, Plains of Dura, Sumter County.	1	8,000		Sulphureted, chalybeate.	Local resort.
Mineral Springs 6 miles southwest of Newnan, Coweta County.	14			Sulphureted, &c	Once a resort, but now unimproved.
Mineral springs:					
Near Toccoa, Habersham County.					
At Clarkesville, Habersham Co.				Chalybeate	
Nine miles from Dahlonega, on Cleveland road, Lumpkin Co.				do	
Mount Airy Springs, Mount Airy, Habersham County.				do	
New Holland Springs, 2 miles east of Gainesville, Hall County.	3	1,200+	55 to 70?	Calcic	Resort.
Oconee Chalybeate Springs, 10 miles from Eatonton, Putnam County.				Chalybeate	Has a local reputation.
Oconee White Sulphur Spring, Bowdre (6 miles from Gainesville), Hall County.	1			Sulphureted	Resort.
Ponce de Leon Spring, Atlanta, Fulton County.		100	66	Chalybeate	Used commercially and as a resort.
Porter Springs, Porter Springs, Lumpkin County.	100	800?	68 to 70	Chalybeate, &c.	Resort.
Powder Springs, Powder Springs, Cobb County.	4	150	58	Sulphureted, chalybeate.	Local resort.
Red Sulphur Springs, Walker County.					
Rowland Springs, Cartersville, Bartow County.				Sulphureted, chalybeate.	
Springfield Spring, Effingham County.					
Sulphur springs:					
At Tallulah Falls, Tallulah, Rabun County.					
In Hall County.					
In Meriwether County.					
Half mile east of Zoar, Bulloch County.					
Thundering Spring, Thomaston, Upson County.					
Trentham Springs, Fairburn, Campbell County.					Unimproved.
Warm Springs, Warm Springs, Meriwether County.		84,000	70 to 90	Sulphureted and chalybeate.	Resort.
Watson's Springs, 11 miles north of Greensborough, Greene County.	5	75	60	Sulphureted, chalybeate.	Local resort.
White Sulphur Springs, White Sulphur Springs, Meriwether County.	5	1,200	56	Sulphureted, saline, and chalybeate.	Resort.

Analyses of mineral springs in Georgia.

Constituents.	Angier's Mineral Springs.	Atlanta Mineral Spring.	Camp's Spring.	Catoosa Springs.			
				No. 9. White Sulphur Spring.	No. 10. Buffalo Spring.	No. 1. All-Healing Spring.	No. 2. Red Sweet Spring.
Solids.	*Grains per gall.* [a]	*Grains per gall.* [a]	*Grains per gall.* [a]	*Grains per gall.* [a]	*Grains per gall.* [a]	*Grains per gall.* [a]	*Grains per gall.* [a]
Sodium carbonate				0.26	0.03	0.25	0.29
Potassium carbonate				0.11	0.01	0.10	0.11
Calcium carbonate		Trace	0.30	3.85	3.85	3.52	3.98
Magnesium carbonate				8.40	8.70	7.02	7.94
Strontium carbonate				0.04	0.04	0.04	0.05
Lithium carbonate				Trace	Trace	Trace	Trace
Manganese carbonate			0.05	0.02	0.02	0.01	0.02
Manganese protocarbonate			0.01				
Iron carbonate				0.28	0.27	0.13	0.14
Iron protocarbonate			2.03				
Iron sesquicarbonate			0.35				
Sodium sulphate				1.67	1.67	1.50	1.70
Potassium sulphate				2.32	2.31	2.20	2.49
Calcium sulphate.	[b]2.5	Trace		44.81	45.00	38.84	43.86
Magnesium sulphate				32.01	33.02	26.54	29.98
Aluminium sulphate				2.47	2.38	0.50	0.66
Strontium sulphate				0.20	0.29	0.20	0.23
Calcium nitrate				0.32	0.03	0.42	0.47
Ammonium nitrate				0.10	0.91	0.12	0.14
Sodium chloride	4.0	2.5	0.13	0.14	0.11	0.18	0.14
Calcium chloride	5.0	4.0	0.12				
Iron sulphide		Trace					
Calcium fluoride				0.01	0.01	0.02	0.02
Magnesium bromide				0.31	0.33	0.30	0.33
Calcium bromide				0.14	0.15	1.21	1.37
Iron sesquioxide (hydrated)	12.5	10.5					
Sodium silicate			0.43				
Calcium silicate							
Sulphuric acid (free)				0.12	0.13	Trace	Trace
Crenic acid			0.02	0.01	0.01	0.02	0.02
Apocrenic acid							
Total	24.0	17.0	3.44	97.59	99.27	83.07	93.94
Gases.	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*
Carbonic acid	Present		2.19	9.55	9.78	1.17	1.16
Hydrogen sulphide			0.47	0.06			
Total			2.56	9.61	9.78	1.17	1.16

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[a] Wm. J. Land, analyst.

[b] With calcium carbonate and iron sulphate.

Analyses of mineral springs in Georgia—Continued.

Constituents.	Catoosa Springs.						Chalybeate Springs.
	No. 4. Chalybeate Spring.	No. 3. Cosmetic Spring.	No. 5. Magnesia Spring.	No. 6. Congress Spring.	No. 7. Alum Spring.	No. 8. Black Sulphur Spring.	
	Grains per gall.[a]	*Grains per gall.*[a]	*Grains per gall.*[a]	*Grains per gall.*[a]	*Grains per gall.*[a]	*Grains per gall.*[a]	*Grains per gall.*[a]
Sodium carbonate	0.26	0.27	0.25	0.26	0.26	0.26	....
Potassium carbonate	0.11	0.11	0.12	0.10	0.13	0.11	....
Calcium carbonate	3.75	3.76	3.84	3.51	3.75	3.84	0.76
Magnesium carbonate	7.48	7.52	8.10	7.02	6.94	7.50	....
Strontium carbonate	0.04	0.04	0.04	0.04	0.04	0.04	....
Lithium carbonate	Trace	Trace	Trace	Trace	Trace	Trace	....
Manganese carbonate	0.01	0.02	0.02	0.01	0.14	Trace	....
Iron carbonate	0.19	0.15	0.17	0.14	0.16	0.18	....
Iron protocarbonate	....	....	....	....	....	....	0.62
Iron sesquicarbonate	....	....	....	....	....	....	0.17
Sodium sulphate	1.59	1.60	1.67	1.50	1.51	1.59	0.12
Potassium sulphate	2.30	1.60	2.32	2.31	2.42	2.32	0.33
Calcium sulphate	41.56	41.58	41.57	38.85	40.80	40.98	....
Magnesium sulphate	27.90	28.40	28.02	26.55	28.97	28.01	....
Aluminium sulphate	0.67	2.36	0.69	0.52	1.10	1.42	0 43
Strontium sulphate	0.20	0.22	0.22	0.20	0.21	0.19	....
Calcium nitrate	0.37	0.41	0.40	0.43	0.35	0.37	....
Ammonium nitrate	0.11	0.12	0.13	0.09	0.10	1.01	....
Sodium chloride	0.14	0.13	0.16	0.13	0.13	0.14	0.03
Silica	....	....	....	....	....	....	2.83
Calcium fluoride	0.02	0.02	0.02	0.02	0.02	0.02	....
Magnesium bromide	0.30	0.31	0.31	0.31	0.31	0.29	....
Calcium bromide	0.12	0.18	0.13	1.11	0.12	0.18	....
Sulphuric acid	0.01	0.01	0.01	0.01	0.01	0.12	....
Carbonic acid	....	4.40	4.30	4.39	4.51	4.50	....
Crenic acid Apocrenic acid	} 0.02	0.02	0.02	0.02	0.01	0.01 {	....
Total	87.15	93.18	92.51	87.52	91.99	93.08	5.30
Gases.	*Cub. ins.*						*Cub. ins.*
Carbonic acid	9.13	....	....	....	....	....	6.55
Hydrogen sulphide	....	....	....	....	....	....	Trace

[a] Wm. J. Land, analyst.

Analyses of mineral springs in Georgia—Continued.

Constituents.	Daniel Mineral Spring.	Franklin Springs.	Helicon Springs.	Indian Springs.		Powder Springs No. 3.	Warm Springs.
Solids.	*Grains per gall.*[a]	*Grains per gall.*[b]	*Grains per imp. gall.*[a]	*Grains per gall.*[c]	*Grains per gall.*[d]	*Grains per gall.*[a]	*Grains per gall.*[e]
Sodium carbonate	......	0.96	......	......	......	......	......
Calcium carbonate	......	0.56	......	......	......	......	......
Magnesium carbonate	......	0.83	0.46	16.17	15.86	2.88	......
Iron carbonate	......	1.04	3.09	......	......	0.06	26.32
Sodium sulphate	1.53	......	0.13	......	......	0.06	......
Potassium sulphate		......	0.10	47.97	27.32	......	......
Calcium sulphate	86.98	0.06	3.22	25.19	57.22	16.54	......
Magnesium sulphate	6.82	0.02	0.07	558.70	572.22	0.56	......
Calcium phosphate	......	......	Trace	......	......	......	......
Sodium chloride	9.86	0.53	0.17	......	......	......	......
Alkaline chlorides	......	......	......	......	......	0.62	......
Alkaline sulphides	......	0.04	......	......	......	0.05	......
Calcium oxide	......	......	......	......	......	......	37.12
Magnesium oxide	......	......	......	......	......	......	93.44
Aluminium oxide	1.46	......	0.05	......	......	......	......
Iron oxide		......	......	......	......	......	......
Manganese	......	......	Trace	......	......	......	......
Silica	1.15	......	0.31	......	......	0.59	......
Silicates	......	......	......	......	......		......
Organic matter	1.36	0.08	0.11	......	......	......	......
Total	108.61	4.12	7.71	648.03	672.62	21.36	156.88
Gases.	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	*Cub. ins.*	
Carbonic acid	......	2.350	5.97	2.61	Undetermined.	......	8.88
Sulphureted hydrogen	......	0.291	......	1.05	7.92	75.00	L'ge am't
Oxygen	......	......	3.12	......	Undetermined.	......	......
Nitrogen	......	......	10.98	......		......	......

[a] H. C. White, analyst.
[b] H. C. White, analyst (1882).
[c] A. A. Hayes, analyst (1857).
[d] John Cotting, analyst (1839).
[e] A. Means, analyst.

FLORIDA.

The springs of Florida are remarkable for their great size rather than for the quantity of mineral matter they contain. Some of the streams proceeding from them are large enough to float steamboats. Very few of the waters have been analyzed, but so far as known, when mineralized, sulphureted hydrogen characterizes the majority of them. Little has been published and definite information is difficult to obtain. Most of the springs in the southern and eastern portions of the State would be classified as weak sulphur springs. In the northeastern portion of the State the waters appear to be more frequently chalybeate. Most of the springs of which the temperatures are given are probably thermal, as they doubtless exceed the mean annual temperature of their localities. The mean annual temperature of Saint Mark's, as given by the Signal Office, is 66°.3 F.; Jacksonville, 69°.2 F.; Pensacola, 68°.5 F.; and Cedar Keys, 71° F.; while Punta Rassa has 73°.6 F. and Key West 77.°3 F. The temperatures of the Florida springs are remarkably uniform summer and winter. They are utilized mainly as winter resorts, and, so far as learned, none of the waters is on sale.

Mineral springs of Florida.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Benson's Salt Spring, Enterprise, Volusia County.	1	500	° 74	Sulpho-saline ...	Resort.
Blue Spring, Orange City, Volusia County	1	73,920	75	Sulphureted ...	Unimproved, but used locally.
Blue Spring, Greenwood, Jackson County.	....	....	......	....	Local resort.
Blue Spring, near Ellaville, Madison County.	....	....	....	Calcic	
Bug Spring, 7 miles east of Sumterville, Sumter County.	....	....	......	....	
Clay Spring, near Apopka, Orange County.	....	....	......	Sulphureted	
Crystal River Springs, Crystal River, Hernando County.	1	....	60	....	
De Barry Mineral Spring, Enterprise, Volusia County.	..	....	......	Sulphureted	
Green Cove Spring, Green Cove Springs, Clay County.	1	3,000	78	....do	Resort.
Hampton Springs, Taylor County....	....	....	......	....	
Hoosier Spring, near Altamonte Station, Orange County.	....	....	......	Sulphureted	
Henson Spring, Enterprise, Volusia County	.	....	......	....	
Linwood Springs, Mount Royal, Putnam County.	3	....	74½	Alkaline, saline, and carbonated.	
Magnesia Spring, near Hawthorn, Alachua County.	...	....	......	....	
Mineral springs:					
Near Ancilla, Madison County.	....	....	......	....	
Near Perry, Taylor County ...	..	....	......	....	
Near Leesburg, Sumter County.	....	....	......	....	
Moncrief Spring, 5 miles from Jacksonville, Duval County.	...	....	72	....	
Mount Royal Springs, Volusia County	....	....	70	....	
Newport Sulphur Springs, near Saint Mark's, Wakulla County.	4	....	70	Chalybeate and sulphureted.	Do.
Orange Spring Orange Springs, Marion County.	1	5,055,000	73	Saline, sulphureted.	Do.
Rock Spring, 6 miles north of Apopka, Orange County.	....	....	......	Sulphureted	
Salt Springs, Marion County............	6	148,000	60	Saline	Used locally.
Silver Spring, Silver Springs, Marion County.	....	....	....	....	
Stevenson's Sulphur Springs, Anclote River, 12 miles from mouth, Hernando County.	2+	....	......	....	Unimproved.
Sulphur springs:					
Near Sumterville, Sumter County. ...	7+	....	......	....	Do.
On Withlacoochee River, 10 miles from Crystal River, Hernando County.	1	....	......	....	
Near Adamsville, Sumter County. ...	3	....	......	....	
Near Tampa, Hillsborough County....	.	....	......	....	
Sumterville Mineral Spring, near Sumterville, Sumter County.	1	....	......	....	
Suwannee Springs, Suwannee, Suwannee County.	...	....	......	....	Resort.
Tarpon Springs, Tarpon Springs, Hillsborough County.	3	....	70	Sulphureted	Do.
Turner Spring, Holmes, Holmes County...	1	....	......	....	Do.
Wakulla Spring, Wakulla Spring, Wakulla County.	1	....	70	Calcic	Do.
Warm Spring, near Sumterville, Sumter County.	....	....	......	....do	Unimproved.
Wesson's Iron Spring, 3 miles from White Springs, Hamilton County.	1	7,500	73	Chalybeate	Resort.
White Sulphur Spring, White Springs, Hamilton County.	1	1,200,000	72	Sulphureted	Do.

Analyses of mineral springs in Florida.

Constituents.	Linwood Springs.	White Sulphur Spring.	Wesson's Iron Spring.	Benson's Salt Spring.
	Grains per gallon.[a]	*Parts in* 1,000,000.[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]
Sodium carbonate		20.91		
Sodium bicarbonate				3.61
Calcium carbonate		80.50	0.28	
Calcium bicarbonate				9.88
Iron carbonate			1.98	
Iron bicarbonate	9.60			
Sodium sulphate	52.80		2.45	5.83
Magnesium sulphate	67.20	25.53	2.63	26.84
Potassium sulphate				2.44
Magnesium bicarbonate				8.90
Sodium chloride	113.60	11.23	0.18	238.24
Potassium chloride		11.32	0.12	
Magnesium chloride	24.80			11.90
Calcium chloride	42.40			40.58
Phosphoric acid		Trace		Trace
Sodium iodide	Trace			
Lithium and ammonia			Trace	
Organic matter	14.40	21.32	1.54	
Loss				
Silica	Trace			1.58
Silica soluble		14.40	1.27	
Sulphureted hydrogen		Present		Not estimated
Iron oxide		1.40		0.43
Alumina oxide				
Total	324.80	186.61	10.45	350.23

[a] A. Connell, analyst (1876).
[b] N. A. Pratt, analyst.
[c] A. Merrill, analyst.
[d] Charles M. Stillwell, analyst (1880).

SOUTHERN CENTRAL STATES.

In the Southern Central States sulphureted and chalybeate springs hold about the same proportion to the whole number of springs as in the South Atlantic States. The number of saline springs, however, is increased and the thermal springs naturally are fewer in number. A large part of the area of this division is occupied by comparatively recent formations; yet, in the northeastern part and in the western, carboniferous rocks, with the underlying sedimentaries, are well developed, and these rocks are almost always prolific in mineral springs. The Hot Springs of Arkansas are the most prominent of the thermal springs. It must be stated here that the returns from the various States, in answer to the questions sent out, are very unequal both as to the extent and the exactness of the information conveyed. In some States (as Kentucky, Tennessee, Alabama, and Arkansas) the geological surveys of the State appear to have paid considerable attention to the subject, and the general public attention has therefore been turned more to the subject and data are more readily obtained.

In Mississippi and especially in Louisiana it has been more difficult to get definite information. No geological surveys of these States have been made very recently. Both States, however, have many springs of excellent mineral water.

Texas is being so rapidly developed as to its resources and so many portions of the State are being newly settled that our list for that State will doubtless be considerably increased in the near future.

In regard to the springs utilized as places of resort and for commercial purposes, the Southern Central States compare favorably with the Southern Atlantic States.

Summary for the Southern Central States.

States.	Number of spring localities.	Number of individual springs.	Number of springs analysed.	Number of springs utilized as resorts.	Number of springs used commercially.	Total number of analyses.
Alabama	82	220	18	22	6	19
Mississippi	82	110	4	13	4	4
Tennessee	177	311	24	62	8	25
Kentucky	142	296	78	21	6	80
Arkansas	108	459	5	24	4	5
Indian Territory	10	15	0	1	0	0
Louisiana	15	28	0	6	0	0
Texas	105	472	13	25	8	13
Total	721	1,911	187	174	36	146

ALABAMA.

Although but few of the Alabama mineral waters are used commercially, there are many springs that are important as places of resort, and several are quite well known throughout the country at large. Bladen Springs, Bailey Springs, and Blount Springs are the ones generally noted in the books. The following list is made up partly from data contained in the geological reports of M. Tuomey and of Eugene A. Smith, but a great many localities have been added as the result of correspondence with persons in all parts of the State. Chalybeate and sulphureted springs are most numerous and are not confined to any portion of the State nor to one geological formation. Two of the best known sulphur springs — Bladon and Tallahatta — rise in the Tertiary, while Blount Springs, equally well known, and also sulphureted, are in the Coal Measures. Sulphur springs also abound in the northern counties, whose rocks belong to the Subcarboniferous limestones. Artesian wells are said to be numerous in the region underlaid by the rotten limestone of the Cretaceous. Such wells are usually highly charged with salts of iron, lime, magnesia, and soda. Comparatively few of the Alabama springs have been analyzed. The analyses presented here have been taken from various sources. Thanks are due to Prof. W. C. Stubbs, State chemist, who has furnished many of them.

Mineral springs of Alabama.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Bailey Springs, Bailey Springs, Lauderdale County.	7	6	° 55 to 60	Chalybeate	Used commercially and as a resort.
Bladon Springs, Bladen Springs, Choctaw County.	5	1,250	67	Carbonated, alkaline, and sulphureted.	Do.
Blount Spring, near Bigbee, Washington County.	1	....	....	Sulphureted ...	Unimproved.
Blount Mineral Springs, Blount Springs, Blount County.	5	900	60	Saline, sulphureted.	Resort.
Blue Grass Sulphur Springs, Cornelia, Saint Clair County.	30+	....	....	Sulphureted and chalybeate.	Do.
Borden Springs, Borden Springs, Cleburne County.	......	....	....	....	Unimproved.
Bowie Springs, near Talladega, Talladega County.	......	....	....	Chalybeate ...	Do.
Burning Spring, Washington County.	......	....	....	....	
Butler Springs, Butler Springs, Butler County.	7	206	60 to 65	....	Used as a resort.
Carmon's Spring, near Fayette Court-House, Fayette County.	......	....	....	....	Unimproved.
Chalybeate springs:					
Near Akron Junction, Hale Co ...	......	....	....	Chalybeate	Do.
Near Claiborne, Monroe County..	......	....	....	....do	
Six miles southwest of Green Springs, Hale County.	......	....	....	....do	Do.
Near Gum Spring, Blount County.	......	....	....	... do	Do.
Six miles north of Jacksonville, Calhoun County.	......	....	....	Chalybeate and sulphureted.	Do.
Near Jasper, Walker County....	6	....	....	....	Do.
On Sand Mountain, Jackson County.	......	....	....	....	Do.
Chandler's Springs, Chandler Springs, Talladega County.	......	....	....	Chalybeate	Used as a resort.
Cliff Springs, 8 miles northwest of Ashville, Saint Clair County.	......	.....	....	....do	
Coffee Spring, Coffee Springs, Geneva County.	1	300	....	Chalybeate and sulphureted.	Do.
Cook's Springs, 20 miles southwest of Ashville, or 5 miles from Wolf Creek, Saint Clair County.	.....	....	....	Sulphureted and chalybeate.	
Callum's Springs, near Bladen Springs, Choctaw County.	3	600	60	Saline, chalybeate, and sulphureted.	Used commercially and as a resort.
Davis Springs, near Elkmont, Limestone County.	2	20	....	....	Unimproved.
Dr. Davis's Spring, Walker County..	......	....	....	Chalybeate	Do.
Ellis's Spring, near Pride's Station, Colbert County.	......	....	......	....do	Used locally.
Franklin Springs, near Russellville, Franklin County.	......	....	....	Saline, chalybeate.	
Golden Springs, near Oxford, Calhoun County.	7	....	....	Saline	Unimproved.
Greene Springs, Green Springs, Hale County.	3	....	63 to 64	Chalybeate ...	Once used as a resort.
Harrell or Chalybeate Springs, near Blount Springs, Blount County.	......	....	58	....do	Partially improved.
Healing Springs, Healing Springs, Washington County.	9	3,100	62 to 65	....	Used commercially and as a resort.
Howell's Spring, 30 miles south of Waterloo, Lauderdale County.	......	....	....	Sulphureted ..	
Jackson Springs, Jackson, Clarke County.	......	....	....	....do	Used locally.
Jenkins's Springs, near Mountain Meadow, Clay County.	8	....	....	Chalybeate	
Johnson's Wells, near Meridianville, Madison County.	......	....	....	....	Do.
Lansford Spring, near Florence, Lauderdale County.	......	....	....	Saline....	

Mineral springs of Alabama—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Lay's Springs, 6 miles east of Greenwood, Etowah County.	4			Chalybeate and sulphureted.	Has a local reputation as resort.
Lee's Spring, near Florence, Lauderdale County.					
Ligon's Springs, Colbert Co., 5 miles from Russellville.					
Livingston Artesian Well, Livingston, Sumter County.	1	50	68	Saline	Resort.
Major Shever Sulphur Springs, near Jasper, Walker County.				Sulphureted	Once had a local reputation.
McCorkle's Spring, 12 miles north of Waterloo. Lauderdale County.				Chalybeate	
Milhour (or Wooley's) Springs, Wooley Springs, Limestone County.	8	75+	47 to 52	Sulphureted	Is a resort.
Mineral springs:					
Near Hatchers, Clay County				do	Unimproved.?
Near Hazel Green, Madison Co.				do	Do.?
Six miles south of State line, Limestone County.				do	Do.?
Near La Fayette, Chambers Co.					Do.
Near Saint Stephens, Washington County.					Do.
Near Village Springs, Blount County.	5				Do.
At Broken Arrow, Saint Clair Co.					
Near Pisgah, Jackson County					Do.?
One mile from Coosada Station, Elmore County.					Do.
Moore's Springs, Maple Creek, near Athens, Limestone County.				Sulphureted	
Newsom's Springs, 9 miles south of Barton, Colbert County.	7				Once a resort.
Pettusville Springs, Pettusville, Limestone County.					Unimproved.
Roper Mineral Wells, Greenville, Butler County.	2	5			Used commercially.
Shelby Springs, near Knight, Shelby County.	7				Resort.
Shocco Springs, near Talladega, Talladega County.				Chalybeate and sulphureted.	
Speaksee Springs, near Bulger's Mill, Tallapoosa County.					Once a resort, but now unimproved.
Stephenson's Springs, near Camp Spring, Lawrence County.					A resort prior to the war.
Stewart's Springs, near Florence, Lauderdale County.	4	80		Saline	Has local reputation.
Sullivan's Mineral Springs, near Bigbee, Washington County.	10			Chalybeate	Local resort.
Sulphur springs:					
One mile from Frankfort, Franklin County.					Unimproved.
Near Bruner, Calhon County					Do.
Eleven miles from Ashville, St. Clair County.					Resort.
Four miles from Springville, St. Clair County.					
Seven miles east of Stevenson, Jackson County.					
On Sulphur Creek, near Athens, Limestone County.					
Sulphur Springs, Sulphur Springs, De Kalb County.					Local resort.
Talladega Sulphur Spring, near Fayetteville, Talladega County.	1			Sulphureted	Resort.
Tallahatta Springs, Tallahatta Springs, Clarke County.	2	24			Do.
Tar Spring. 9 miles south of Oakville, Lawrence County.					Unimproved?
Tar Springs, 8 miles south of Dickson, Colbert County.					Local resort.

Mineral springs of Alabama—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Taylor's Springs, 1 mile from Florence, near Centre Star, Lauderdale County.	4	80		Alkaline	
Tecumseh Sulphur and Chalybeate Springs, Tecumseh, Cherokee County.					Unimproved.
Todd Spring, near Bailey Springs, Lauderdale County.					Do.
Valhermosa Springs, Valhermosa Springs, Morgan County.					Resort.
Waterloo Mineral Spring, 1 mile from Waterloo, Lauderdale County.				Chalybeate?	Used locally.
West's Mineral Spring, Walker County.				do	Unimproved?
White Sulphur Springs, near Elkmont, Limestone County.					Do.
White Sulphur Springs, 6 miles east of Jacksonville, Calhoun County.	21			Chalybeate and sulphureted.	Used commercially and as a local resort.
Witherspoon Spring, near Florence, Lauderdale County.					
Wyndham Springs, near Oregonia, Tuscaloosa County.				Chalybeate and sulphureted.	Once a resort.

Analyses of mineral springs in Alabama.

Constituents.	Bladon Springs.			
	Vichy Spring.	Branch Spring.	Sulphur Spring.	Old Spring.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[b]
Sodium carbonate	46.33	41.21	34.93	32.89
Magnesium carbonate	0.29	0.61	0.65	1.36
Calcium carbonate	0.87	2.14	2.42	2.75
Iron carbonate	0.49	0.23	0.76	0.02
Calcium sulphate	2.25	2.79	2.96	....
Iron sulphate	....	....	....	0.24
Sodium chloride	....	....	....	7.69
Strontia	....	....	....	0.32
Silica	....	....	....	2.10
Organic matter	2.26	1.90	1.25	....
Crenic acid	....	....	....	0.78
Hypocrenic acid	....	....	....	0.60
Total	52.49	48.88	42.97	48.70
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	65.44	59.20	52.88	32.56
Sulphureted hydrogen	....	....	0.56	....
Chlorine	1.84	1.84	1.84	....
Total	67.28	61.04	55.28	32.56

Constituents.	Cullum's Springs.			Livingston Artesian Well.
	Alabama Vichy Spring.	Sulphur Spring.	Ferruginous Spring.	
Solids.	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[a]	*Grains per gallon.*
Sodium carbonate	....	57.28	0.355	....
Sodium bicarbonate	65.40	....	....	....
Potassium bicarbonate		11.28	....	....
Magnesium bicarbonate	6.49	1.64	....	2.320
Calcium bicarbonate		1.60	....	7.140
Iron bicarbonate	0.37	....	9.640	0.204
Sodium sulphate	2.46	1.93	....	....
Magnesium sulphate		0.52	....	....
Iron perchloride	....	....	....	0.190
Potassium chloride	....	....	1.170	0.825
Sodium chloride	4.54	6.53		295.4[illegible]5
Magnesium chloride	....		0.520	1.839
Calcium chloride	....	....	....	2.983
Sodium iodide	Trace	Trace	....	....
Sodium bromide	....	....	....	0.980
Silica	1.40	1.22	....	....
Sodium silicate	1.57		....	....
Aluminium silicate	(?)	....	3.320	....
Silicates	....	....	....	1.188
Strontia	....	....	....	Trace
Bitumen	....	....	0.818	....
Organic mattter	2.60	3.62		....
Glairine	....		....	....
Total	84.83	85.62	15.823	312.554
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches*
Carbonic acid	Trace	....	....	21.47
Sulphureted hydrogen	....	97.10	....	....
Carbonic acid in combination	....	....	....	9.32
Total	....	97.10	....	30.79

[a] J. L. and W. P. Riddell, analysts.
[b] R. T. Brumby, analyst.
[c] Abequin, analyst (1858).

Analyses of mineral springs in Alabama—Continued.

Constituents.	Blount Mineral Springs.			
	No. 1. Red Spring.		Sweet Spring.	Spring No. 4.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[a]	*Grains per gallon.*[c]
Magnesium carbonate	4.40	3.67	3.60	9.40
Calcium carbonate	6.30	7.23	4.48	5.72
Barium carbonate				0.91
Iron carbonate	1.92		1.12	3.19
Sodium sulphate		0.89		
Magnesium sulphate	1.60		2.40	
Calcium sulphate		0.28		1.27
Calcium phosphate				Trace
Potassium chloride				7.07
Sodium chloride	32.82	29.86	30.88	23.21
Magnesium chloride	6.00	0.78		2.04
Iodides		Trace		
Magnesium iodide				0.14
Magnesium bromide				0.16
Lithium				Trace
Alumina		[d]3.00		Trace
Silica				2.44
Sulphur		2.07		
Total	53.04	47.78	42.48	55.55
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	6.00		6.00	4.72
Sulphureted hydrogen	14.96		12.56	30.67
Oxygen				7.08
Nitrogen				

Constituents.	Talladega Spring.	Roper Mineral Wells.	Johnson's Wells.	Harrell Springs.
Solids.	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[e]	*Parts in* 1,000.[e]
Sodium carbonate	12.32			
Potassium carbonate	7.99			
Magnesium carbonate	0.93			
Calcium carbonate	8.78			
Iron carbonate	Trace			6.00
Magnesium sulphate				1.00
Calcium sulphate	10.89			3.00
Magnesium phosphate				0.50
Sodium chloride	5.34			
Soda		1.55	27.76	
Potash		8.55	1.55	
Magnesia		17.61	0.22	
Lime		40.47	18.91	
Lithium				Trace
Aluminic oxide			12.41	
Alumina	1.45			
Silica	2.45	10.32	1.16	
Ferrous oxide		66.72		
Ferric oxide		116.58	Trace	
Chlorine		2.39	44.24	
Organic matter			1.98	Trace
Carbonic anhydride		21.58	10.50	
Sulphuric oxide		315.85	39.45	
Total	50.15	601.62	158.18	10.50
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen	82.00			

[a] R. Brumby, analyst.
[b] Henry Leffmann, analyst.
[c] W. C. Stubbs, analyst.
[d] With phosphates.
[e] Summers, analyst.

Analyses of mineral springs in Alabama—Continued.

Constituents.	Taylor's Springs.		
	Spring No. 1.	Spring No. 2.	Spring No. 3.
	Grains per gallon.[a]	*Grains per gallon.*[a]	*Grains per gallon.*[a]
Sodium bicarbonate	0.42	0.49	0.43
Magnesium bicarbonate	0.58	0.64	0.55
Calcium bicarbonate	1.03	1.30	1.09
Iron bicarbonate	0.26	0.23	0.25
Sodium sulphate	0.03	0.03	0.03
Magnesium sulphate	0.02	0.03	0.03
Potassium chloride	Trace	Trace	Trace
Sodium chloride	0.12	0.08	0.07
Magnesium chloride	0.12	0.06	0.11
Calcium chloride	0.14	0.07	0 07
Alumina	Trace	Trace	Trace
Silica	0.29	0.32	0.26
Organic matter	0.81	1.01	1.54
Loss	....	0.04	....
Total	3.82	4.30	4.43

[a] J. Lawrence Smith, analyst.

MISSISSIPPI.

The mineral springs of Mississippi are numerous, and, like those of the neighboring States, are largely chalybeate. In certain localities the greater portion of the wells and springs are highly mineralized. Waile's report on the geology of Mississippi states that, along the whole extent of the Yazoo and Tallahatchee Valleys and the whole front below, on the Mississippi River, copious springs issue from the bluffs, the water flowing from beds of ocherous earth and pyritous clays. The water is highly charged with sulphate of iron and its habitual use is very pernicious. Many of the artesian wells of the State are also mineralized. Prof. E. W. Hilgard, in his geological report for 1860, says: "Few neighborhoods in the State are without a mineral spring or well of some kind, good, bad, or indifferent." Many of these springs have extensive local reputations and appear to be used somewhat indiscriminately by the residents for medicinal purposes. Only a few of the springs have any commercial importance. Ocean Springs and Iuka Springs are the best known resorts. Cooper's Well was well known before the war and, with others, is being revived as a pleasure resort.

Mineral springs of Mississippi.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alkaline spring:			°		
One mile east of Yazoo City, Yazoo County.	......	....	62	Alkaline........	
Alum springs:					
In La Fayette County	......	....	....	....	
In Madison County	......	....	....	....	
In Marion County	......	....	....	....	
In Pike County.	......	....	....	....	
Anchosa Spring, Anchosa Creek, near Quitman, Clarke County.	......	....	....	....	
Artesian Springs, 6 miles from Pickens, near Camden, Madison County.	4	....	....	Chalybeate	Resort.
Artesian Well (public), 512 feet, Aberdeen, Monroe County.	1	600	....	....do	
Belmont Springs, 3½ miles northeast of Buckatunna, Wayne County.	2+	3, 600	....	....	Do.
Black Wells, Choctaw County	......	....	....	Saline, chalybeate.	
Brandywine Spring, 20 miles east of Port Gibson, Claiborne County.	...	....	....	Sulphureted	Once a resort.
Calhoun Springs, near Pittsborough, Calhoun County.	......	......	....	....	Do.
Castalian Springs, near Durant, Holmes County.	5	7, 200	58	Sulphureted, saline, and chalybeate.	Used as a resort and commercially.
Chalybeate Acid Springs, 2 miles southwest of Grenada, Grenada County.	1+	....	75	Chalybeate, &c.	Used as a resort to a limited extent and sold.
Chalybeate springs:					
Near Poplar Springs, Calhoun Co.	......	....	....	....	Unimproved.
In T. 1. R. 16, southeast of De Soto, Clarke County.	......	....	....	....	
Near Enterprise, Clarke County	......	....	64.4	....	
Near Fulton, Itawamba County..	2	....	62	....	
Southeast of Fulton, Itawamba Co.	. ..	....	....	....	
Near Eureka Springs, Panola Co.	......	....	....	Chalybeate	
Near Warren's Mill. on Mackay's Creek. Tishomingo County.	...	....	....	....	
In Winston County	......	....	....	....	
In Yalobusha County	......	....	....	....	
In Sec. 26, T. 6, R. 9 E., Tishomingo County.	......	....	....	....	
In Sec. 34, T. 5, R. 10 E., Tishomingo County.	.....	....	....	....	
North of Houston, Chickasaw Co	......	....	....	....	
Near Jonesboro'. Tippah County	......	....	....	....	
Six miles northwest of Ripley, Tippah County.	......	....	....	....	
Southwest of Satartia. Yazoo Co	......	....	....	....	
One mile south-southwest of Grenada, Grenada County.	......	....	75.2	....	
Near Louisville, Winston County.	......	....	....	....	
Near Oxford, La Fayette County.	......	....	....	....	
Near Robina, Panola County. ...	......	....	....	....	
Three miles northeast of Vernal, Greene County.	.....	....	....	....	
Near Cross Roads, Greene County	......	....	....	....	
Near Westville, Simpson County.	......	....	....	....	
In Rankin County	......	....	....	....	
Coleman's Well, Jackson County .	......	....	....	....	
Columbia Springs, Columbia, Marion County.	......	....	....	....	
Cooper's Well (artesian), 4 miles from Raymond, Hinds County.	1	....	55	Saline	Used commercially and as a resort.
Franklin Springs, head of Well's Creek, Franklin County.	......	....	64	....	Once a resort.
Godbold Mineral Well, near Summit, Pike County.	1	....	....	....	Used commercially and as a resort.
Greenwood Spring, Monroe County..	......	....	....	....	
Harrison Springs (see Belmont Springs).					
Hazel Dell Springs, 2½ miles from Holly Springs, Marshall County.	3	....	....	Chalybeate	Used as a local resort.

Mineral springs of Mississippi—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Holsom-Back Springs, 8 or 10 miles southwest of Louisville, Winston County.	......	....	....	....	Local resort.
Iuka Mineral Springs, near Iuka, Tishomingo County.	4	....	60	Chalybeate and sulphureted.	Resort.
La Fayette Springs, La Fayette Springs, La Fayette County.	......	....	....	Saline, sulphureted.	Do.
Lauderdale Springs, near Lauderdale Station, Lauderdale County.	......	....	....	Sulpho-chalybeate.	
Mineral springs:					
Near Poplar Springs, Union County.	......	....	....	....	Unimproved.
At Holmes Mill, near Fearn's Springs, Winston County	......	....	....	....	Once a resort.
Near Corinth, Alcorn County ...	......	....	....	....	
In Sec. 24, T. 16, R. 3 E., Holmes County.	......	....	60.8	Acid-chalybeate	
At Pittsborough, Calhoun Co....	...	....	63	....	
At Mount Pleasant, Marshall Co	......	....	....	....	
At Canton, Madison County.	......	....	....	Sulpho-chalybeate.	
Near Brandon, Rankin County ..	......	....	....	....	
Near Steen's Creek, Rankin County.	......	....	....	....	
At West Pascagoula, Jackson County.	......	....	....	....	
Near Handsborough, Harrison County.	......	....	....	....	
In Sec. 30, T. 6, R. 9, near Hazel Dell, Prentiss County.	2	....	....	Sulpho-chalybeate.	Used locally.
Twelve miles northeast of Columbus, Lowndes County.	....	....	....	....	
Mineral Wells, 8 miles below head of Well's Creek, Franklin County.	......	....	....	....	
Mississippi Springs (once Bankston Springs), near Raymond, Hinds County.	4	....	....	Sulphureted ..	Used as a resort prior to 1868
Multona Springs, 4 miles from McCool, Attala County.	7	....	....	....	Unimproved.
Ocean Springs, Ocean Springs, Jackson County.	......	....	....	....	Resort.
Quitman Red Sulphur Springs, or Archusa Springs, ¾ mile south of Quitman, Clarke County.	2	500+	....	Sulpho-chalybeate.	Local resort.
Smith's Springs, south of Quitman, Clarke County.	......	....	....	....	
St. Andrew's Well, 1 mile south of Monticello, Lawrence County	......	....	....	....	
St. Ronan's Well, 4 miles south of Monticello, Lawrence County.	......	....	....	....	
Stovall's Spring, 3 miles above Columbia, Marion County.	1	....	....	Chalybeate ..	Used to a limited extent for medicinal purposes.
Sulphur springs:					
Near Enterprise, Clarke County	......	....	....	....	
Eight miles south of Philadelphia, Neshoba County.	1	....	....	....	
Near Philadelphia, Neshoba Co..	1	....	....	....	
Near Central Academy, Panola Co.	....	... .	....	....	
In Neshoba County	......	....	....	....	
Tipton Well, Jackson County .	......	....	....	....	
Vernal Springs, 3 miles south of Vernal, Greene County.	......	....	....	....	Unimproved
Winston Springs, near Louisville, Winston County.	......	....	....	....	Resort.
White Springs, 3½ miles northwest of Ripley, Tippah County.	2	....	40	....	Used locally.
White's Springs, 4½ miles south of Fulton, Itawamba County.	8	....	....	....	Local resort.
White Sulphur Springs, near Garlandville, Jasper County.	......	....	....	....	

Analyses of mineral springs in Mississippi.

Constituents.	Godbold Mineral Well.	Cooper's Well.	Lauderdale Springs.	Ocean Springs.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Parts in* 100.[c]	*Grains per gallon.*[b]
Calcium carbonate	Trace			
Sodium sulphate		11.71		
Potassium sulphate		0.61		
Calcium sulphate	Trace	32.18		
Aluminium sulphate		6.12		
Magnesium sulphate		23.28		
Sodium chloride	1.73	8.36		47.77
Potassium chloride				Trace
Calcium chloride		4.32		3.88
Magnesium chloride		3.48		4.97
Iron protochloride	11.42			
Silica	Trace		0.00100	
Alumina			0.00005	
Ferrous oxide				4.71
Loss	0.84			
Iron peroxide		3.36	0.00047	
Crenate of lime		0.31		
Crenate of silica (?)		1.80		
Organic matter				Trace
Lime			0.00014	
Sulphur combined with hydrogen			0.00034	
Potash			0.00012	
Soda			0.00226	
Ammonia			Trace	Trace
Magnesia			Trace	
Sulphuric acid			0.00008	
Carbonic acid			0.00007	
Chlorine			0.00062	
Iodine			0.00006	Trace
Apocrenic acid			0.00008	
Crenic acid			0.00002	
Hydrogen combined sulphate			0.00002	
Bromine			Trace	
Total	13.99	95.48	0.00583	61.33
Gases.				*Cubic inches.*
Sulphureted hydrogen			0.23397	1.28
Carbonic acid uncombined			0.25766	9.76
Oxygen and nitrogen			0.25728	
Carbureted hydrogen			Trace	
Total			0.74891	

[a] J. H. Laster, analyst.
[b] J. Lawrence Smith, analyst.
[c] L. Harper, analyst (1857).

TENNESSEE.

The mineral springs of Tennessee are numerous and occur in all portions of the State. The geological formations being the same as those of the adjacent States, especially of Virginia, Kentucky, Alabama, and Mississippi, the mineral springs are naturally of the same general character. Chalybeate and sulphureted springs, therefore, predominate. Killebrew and Safford's Resources of Tennessee probably gives as complete an enumeration of the springs as any work published. The list presented here is largely indebted to it, and in addition has had the supervision of Prof. James M. Safford, State geologist of Tennessee. Acknowledgment is also due to him for copies of analyses made by himself and by Prof. N. T. Lupton.

A large number of the springs are used as resorts. Many that were so frequented prior to the war have fallen into disuse, and other springs of extensive local reputation are still unimproved. Notwithstanding the number of springs utilized, complete analyses of comparatively few have been made:

Mineral springs in Tennessee.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alleghany Springs, 14 miles south of Maryville, Blount County.	8	300+	° 59	Chalybeate, sulphureted.	Resort.
Alum and Chalybeate Springs, on Beaver Dam Creek, Benton County.	....	....	......	....	
Alum Springs, near Rogersville, Hawkins County.	3	....	......	....	
Alum Well, 5 miles east of Rogersville, Hawkins County.	1	....	......	....	Unimproved.
Artesian Well (sulphur), 2 miles from Saltillo and ½ mile north of White Oak River, Hardin County.	....	....	......	Sulphureted ...	
Artesian Well, Swayne's Mineral Spring, 9 or 10 miles from mouth of Big Sandy and 4 miles from Springville, Henry County.	1	....	......	Sulphureted	Was once a famous resort; not much used at present.
Austin's Springs, Austin's Springs, Washington County.	2	60	51	Saline, chalybeate.	Resort.
Avoca Spring, near Bristol, Sullivan County.	1	50	......	Sulphureted	Used locally.
Banner's Springs, 4 miles from Dandridge, Jefferson County.	....	....	......	Sulphureted	Resort.
Bath Springs, Decatur County, 7 miles northwest of Clifton.	2	....	......	Sulphureted	Was once a resort; unimproved now.
Beaver Dam Springs, southern part of Hickman County.	....	....	......	Sulphureted	Resort.
Beersheba Springs, Beersheba Springs, Grundy County.	....	....	......	Chalybeate	Do.
Black Sulphur Springs, Blount County.	.	....	......	....	
Black Water Springs, near Bean's Station, Grainger County.	3	....	......	Sulphureted and chalybeate.	Do.
Bon Air Chalybeate Spring, on edge of Cumberland tableland, 5 miles from Sparta, White County.	....	....	......	Chalybeate	Resort prior to the war.
Bon Aqua Springs, formerly Weem's Springs, Hickman County, 7 miles south of Burns.	....	....	......	Calcic, sulphur .	Resort.
Brown's Springs, near Union Depot, Sullivan County.	....	....	......	....	
Brown and Boyd's Spring, Rhea Co., 5 miles from Pikeville.	....	....	......	Chalybeate	
Canwood's Springs, 2 miles south of Dandridge, Jefferson County.	....	....	......	Chalybeate and sulphureted.	Do.
Cascade Springs (formerly Pylant's), Franklin Co., 5 miles from Tullahoma.	6	....	......	Alkaline, sulphureted.	Do.
Castalian Springs, Castalian Springs, Sumner County.	6	12,000+	......	Saline, sulphureted,	Was a resort to limited extent before the war.
Cavco's Springs, 6 miles from Franklin, Williamson County.	...	....	......	....	Resort.
Chalybeate springs:					
In Washington County...	....	....	......	Chalybeate	
Near Huntingdon, Carroll County.	....	....	......	....	
Near Jacksborough, Campbell Co.	....	....	......	....	
At Elizabethton, Carter County ..	....	....	......	....	
Two miles south of Crossville, Cumberland County.	....	....	......	....	
Ten miles south of Crossville, Cumberland County.	...	....	......	....	
Near Rockport, Benton County ...	....	....	......	....	
Four miles from Pikeville, Bledsoe Co.	1	....	......	....	Unimproved.
East of Smithville, De Kalb Co....	2	10+	......	Sulpho-chalybeate.	
In Fentress County........	....	....	......	....	
In Hardin County	....	....	......	....	
Two miles east of Paris, Henry Co	....	....	......	....	Used locally.
In Big Poor Valley, northeast of War Gap, Hawkins County.	..	....	......	....	

Mineral springs in Tennessee—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Chalybeate springs—Continued.			°		
At Mill Spring, Jefferson County	....	....	......	....	
Ten miles south of Dandridge, Jefferson County.	....	....	......	....	
Near Jasper, Marion County	....	....	......	....	
Twenty miles southeast of Livingston, Overton County.	1	....	......	....	
On Roaring Fork, Overton County	....	....	......	....	
At Alpine, Overton County	1	....	......	....	
Near Jackson, Madison County	3	....	......	....	Resort.
At Pilot Knob, near Monroe, Overton County.	1	....	......	....	
On Turkey Creek, Madison County	....	....	......	....	
In Wear's Valley, south of Sevierville, Sevier County.	....	....	......	....	
In Sullivan County	....	....	......	....	
One mile south of Spencer, Van Buren County.	....	....	......	....	
Chilhowee Spring, Chilhowee Mountain, near Williamsburg, 1 mile south of Kimbrough's Store, McMinn Co.	1	300–400	......	Chalybeate	Used to small extent locally.
Clinchdale Springs, Bean's Station Valley, Grainger County.	12	....	......	Chalybeate and sulphureted.	Unimproved.
Clarktown Springs, Clarktown, 11 miles east of Sparta, White County.	4	....	......	Chiefly chalybeate.	Resort.
Cooper's Springs, 1½ miles east of Kimbrough's Store, McMinn Co.	....	....	......	....	
Copeland Springs, near White Pine, 6 miles east of Dandridge, Jefferson County.	...	....	......	Sulphureted and chalybeate.	Do.
Crawford Spring, Henderson County, 16 miles east of Jackson.	....	....	......	....	
Crisp Springs, 6 miles from McMinnville, Warren County.	....	....	......	Alkaline, sulphureted.	
Dixon's Oakland Spring, 2 miles from Fern River, near Perryville, Decatur County.	1	300	......	Sulphureted	Used locally.
Draper's Springs, Bloomington, Putnam County.	3	....	57	Chalybeate and sulphur.	Resort.
Dunlap's Chalybeate Springs, 2½ miles south of Bolivar, Hardeman County.	4	....	......	Sulphur and chalybeate.	Was a resort prior to the war.
Dunn's Spring, Davidson County	....	....	......	....	
Eldorado Springs, Chancy, Robertson County.	6	....	......	Sulphureted	Resort.
Ellmont Springs, near Elkton, Giles Co.	3+	....	57–60	Chalybeate	Do.
Epperson Springs, west part of Macon County.	5	....	40	Chalybeate and sulphur.	Do.
Epsom Springs, 7 miles northeast of Rogersville, Hawkins County.	....	....	....	....	
Erwin Spring, Erwin, Unicoi Co	1	200+	......	Chalybeate	Do.
Estill Springs, Spring Hill, Estill Springs, Franklin County.	3	....	....	Chalybeate and alkaline, sulphureted.	Used as a resort to limited extent.
Fernvale Springs (formerly Smith's), 12 miles west of Franklin, Williamson County.	3	45+	63½	Sulphureted and calcic.	Resort.
Galbraith's Springs, Galbraith's Springs, near Mooresburg, Hawkins County.	4	60+	......	Chalybeate	Do.
Gibson's or Academy Springs, 18 miles east of Crossville, Cumberland Co.	3	....	......	....	Unimproved.
Gibson Wells, 9 miles southwest of Trenton, Gibson County.	3	....	......	....	Resort.
Glenn's Chalybeate Spring, 1½ miles east of Randolph and 7 miles west of Atoka, Tipton County.	1	....	......	Alkaline, carbonated.	Do.
Glover's Springs, near Union Depot, Sullivan County.	2	200	......	Chalybeate	Do.
Graham's Springs, near Rebecca, Franklin County.	....	....	......	Calcic, alkaline, sulphureted.	Do.
Hager's Spring, Sumner County	....	....	......	Sulphureted	
Hale's Red and White Sulphur Springs, Hale's Springs, 6 miles northwest of Rogersville, Hawkins County.	3	....	58	Sulphureted and chalybeate.	Do.

Mineral springs in Tennessee—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks.
Hale and Goff's Springs, near Spencer, Van Buren County.					
Harris Sulphur Springs, 2 miles from Ashland City, Cheatham County.					
Henderson's Springs, Henderson's Springs, Sevier County.					
Hinson Spring, Henderson County, 28 miles east of Jackson.	1			Chalybeate	Resort.
Horn's Mineral Springs, near Lebanon, Wilson County.				Alkaline, saline	Resort and the water is sold to limited extent.
Howard Springs, Howard Springs, 4 miles west of Crossville, Cumberland County.	4	400+	45–60	Chalybeate	Resort.
Hurricane Springs, Franklin County, 6 miles from Tullahoma.	3	12	54	Alkaline, sulphureted.	Sold to limited extent and a resort.
Idaho Springs, Saint Bethlehem, near Clarksville, Montgomery County.	6	60+	56		Used commercially and as a resort.
Jenkins White Sulphur Springs, Carter County.					
Jones's Sulphur Well, 1 mile west of Murfreesborough, Rutherford Co.				Alkaline, sulphureted.	
Jordan's Springs, Jordan's Springs, Montgomery County.	8	6,000+	40		Used locally.
King's Sulphur Springs, Cheatham Co.					
Kingston Springs, Kingston Springs, Cheatham County.	5		57–60	Sulphureted and chalybeate.	Resort.
Klippert's Spring, near Hale's Springs, Hawkins County.	1			Chalybeate	Do.
Lea's Springs, near Spring House, Grainger County.	7				Do.
Line Spring, Line Spring, Sevier Co	1			Chalybeate	Local resort.
Low's Sulphur Springs, near Fairview, Anderson County.					Unimproved.
Mack's Sulphur Springs, 6 miles south of Maryville, Blount County.					Improved.
McBride's Spring, 3 miles from Spencer, Van Buren County.	1	60			Local resort.
McEwen's Springs, 1 mile from Franklin, Williamson County.					Resort.
Melrose Springs, near Maryville, Blount County.	4			Sulphureted and chalybeate.	Do.
Mineral springs:					
Near Pikeville, Bledsoe County				Chalybeate	
In Cocke County				Chalybeate, &c.	
At foot of Cumberland Gap, Claiborne County.					
Two miles west of Alamo, Crockett County.					
In James County					
Near Chestnut Hill, Jefferson Co.					
In Poor Valley, Knox County					
In McMinn County					
Near Mont Eagle, Marion Co.	4				Do.
In Perry County					
In Putnam County					
At Neshoba, Shelby County					
At Raleigh, Shelby County					
On Clinch River, Union County				Sulphur	Unimproved.
Six miles north of Maynardville, Union County.				Chalybeate	Do.
Mineral Hill Springs, near Bean's Station, Grainger County.	8	400+		Sulphureted	Used commercially and as a resort.
Montvale Springs, Montvale, Blount County.	3	200+	45–50	Chalybeate and sulphur.	Resort.
Mooresburg Spring, near Mooresburg, Hawkins County.				Chalybeate	Do.
Morgan Springs, Rhea County, 6 miles from Pikeville, Bledsoe County.				do	
Mount Nebo Springs, Blount County					
Nashville Sulphur Spring (artesian), Nashville, Davidson County.				Saline, sulphureted.	Much used by people of Nashville.
Norwood Springs, Rhea Co., 1½ miles from Pikeville, Bledsoe County.				Chalybeate	

Mineral springs in Tennessee—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Oliver Springs, Oliver Springs, Anderson County.	6	150+	......	Sulphureted and chalybeate.	Resort.
Parker's Sulphur Spring, near Big Sandy, Benton County.	1	......	......	......	Local resort.
Patterson's Springs, near Birdsville, Cocke County.	......	......	......	......	Resort.
Pettigrew White Sulphur Springs, 9 miles from Perryville, Decatur Co.	......	......	......	......	
Pickwick White and Red Sulphur Springs, near Walnut Grove, Hardin County.	......	......	......	......	Do.
Powder Springs, Powder Spring Gap, Grainger County.	......	......	......	......	Unimproved at present.
Primm's Springs, east part of Hickman County.	5	515+	58-68	Calcic, sulphureted.	Resort.
Price's Chalybeate Spring, 6 miles from Erie, London County.	1	......	......	Chalybeate......	Local resort.
Raleigh Mineral Springs, Raleigh, near Memphis, Shelby County.	6+	......	53-74	......	
Red Boiling Springs, Red Boiling Springs, Macon County.	3+	......	......	Sulphureted and chalybeate.	Used commercially and as resort.
Red Sulphur Springs, 5 miles south of Pyburn's Bluff, Hardin County.	3	......	......	......	
Rhea Springs, Rhea Springs, Rhea County.	2	480	56	Alkaline, saline, chalybeate.	Used commercially and as a resort.
Robinson's Springs, 20 miles from Nashville. Davidson County.	......	......	......	......	
Robinson Spring, Chalybeate, Van Buren County.	1	120	......	Chalybeate......	Resort.
Sam's Creek Springs, Davidson Co......	......	......	......	......	
Shady Grove Springs, 4 miles southwest of Dandridge, Jefferson Co.	......	......	......	Chalybeate and sulphureted.	Do.
Shelby Chalybeate Springs, Nashville, Davidson County.	......	......	......	......	
South Saratoga Springs, 10 miles from Pikeville, Bledsoe County.	......	......	......	......	Do.
Sulphur springs:					
On Sulphur Creek, Benton County.	1	60	51	......	Local resort.
In Clay County......	......	......	......	......	Small and unimportant.
At Cascade Falls, near Tullahoma, Coffee County.	......	......	......	......	
Three miles from Stephen's Chapel, Bledsoe County.	......	......	......	......	Unimproved.
In Dyer County......	......	......	......	......	
At Van Buren Academy, Fentress County.	......	......	......	......	
Near Locust Spring, Greene Co......	......	......	......	......	
In Hamblen County......	......	......	......	......	
Three miles from Saltillo, Hardin County.	1	100	......	......	Do
Four miles west of Dandridge, Jefferson County.	......	......	......	......	
Four miles south of White Pine, Jefferson County.	1	......	......	......	Resort.
Seven miles south of Livingston, Overton County.	......	......	......	......	Local resort
Near Jefferson, Rutherford Co......	......	......	......	......	
Near Murfreesborough, Rutherford County.	......	......	......	......	
Near Huntsville, Scott County......	......	......	......	......	
Eight miles east of Blountville, Sullivan County.	......	......	......	......	
Five miles west of Union Depot, Sullivan County.	......	......	......	......	
In Tipton County......	......	......	......	......	
Between Districts 7 and 10, Weakley County.	......	......	......	......	
Sulphur wells:					
At Alexandria, De Kalb County......	......	......	......	......	
Near Liberty, De Kalb County......	......	......	......	......	
Near Brentwood, Williamson Co......	......	......	......	......	Unimproved.
Near Nolensville, Williamson Co......	......	......	......	......	
Near Petersburg, (?) Williamson Co.	......	......	......	......	

Mineral springs in Tennessee—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Sulphur wells—Continued.					
Three and one-half miles northeast of Sparta, White County.					
At Clarktown, near Solon, White Co					Unimportant.
Tate's Epsom Spring, Tate Springs, Grainger County.	1	120	55	Saline, chalybeate.	Commercially and as a resort.
Terries Springs, Rutherford County					
Tilford's Mineral Well, Wartrace, Bedford County.				Alkaline	
Tyree's Springs, Davidson County					
Wayland's Springs, Wayland Springs, Lawrence County.	4	150+	60	Saline, chalybeate.	Resort.
West Nashville Sulphur Well, Nashville, Davidson County.				Saline, sulphureted.	Sold to limited extent.
Winchester Sulphur Springs, Franklin County.					Resort prior to the war.
White Cliff Springs, in Chilhowee Mountain, 16 miles from Mouse Creek, Monroe County.	3+			Chalybeate, sulphureted.	Resort. (?)
White Creek Springs, 12 miles from Nashville, Davidson County.				Sulphureted	Resort.
White Fern Springs, Henderson Co., 14 miles east of Jackson.					
White Sulphur Spring, near Witt's Foundry, Hamblen County.	1		45	Sulphureted	Unimproved.
White Sulphur Spring, 1 mile south of Pyburn's Bluff, Hardin County.	1	20			Resort.
White Sulphur Springs, in Sumner County, near Whitehouse.					
Wood's Springs, near Miles Cross-Roads, Clay County.	3				Used locally.
Yeager's Springs, Washington County.	2				
Yellow Sulphur Springs, near Montvale, Blount County.					
Yellow Sulphur Springs, Carter Co					

Analyses of mineral springs in Tennessee.

Constituents.	Austin's Springs.	Cascade or Pylant's Springs.	Crisp Springs.	Fernvale Springs.	Galbraith's Springs.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate			6.30		
Calcium carbonate	3.20	9.23	16.91	6.48	3.84
Magnesium carbonate		5.52	1.43	7.04	0.47
Lithium carbonate			Trace		Trace
Iron carbonate	Trace				0.41
Sodium sulphate	2.40	12.68		13.76	0.22
Calcium sulphate	4.80	4.65	28.45	27.60	0.91
Magnesium sulphate	11.20		15.17		
Potassium sulphate		2.85	0.78	1.12	0.16
Lithium sulphate				Trace	
Iron sulphate	6.40				
Sodium hyposulphite			0.89		
Calcium nitrate					Trace
Sodium phosphate			Trace		
Calcium phosphate		0.04			Trace
Sodium sulphide		9.76	1.85	8.32	
Iron sulphide (in suspension)			Trace		
Sodium chloride	0.80	14.15	5.45	8.88	0.08
Lithium chloride		0.22			
Magnesium iodide		0.05			
Magnesium bromide		0.56			
Aluminium oxide	2.00	0.09	0.06	0.56	0.04
Iron oxide	11.20				
Silica		0.58	0.41	0.08	0.68
Iodine	Trace		Trace		
Bromine			Trace		
Loss	4.00				
Total	46.00	59.88	77.20	73.84	6.81
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen		23.04	9.47	14.64	

[a] Alpheus Dove, analyst.
[b] N. T. Lupton, analyst (1877).
[c] J. M. Safford, analyst (1884).
[d] N. T. Lupton, analyst (1879).
[e] W. A. Noyes, analyst (1884).

Analyses of mineral springs in Tennessee—Continued.

Constituents.	Glenn's Chalybeate Spring.	Hurricane Springs.	Jones's Sulphur Well.	Montvale Springs.	
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate	1.58	6.48	7.74		
Calcium carbonate	9.64	6.95	4.85	13.26	
Magnesium carbonate	7.10	3.98	2.17		
Potassium carbonate	0.05				
Lithium carbonate			0.02		
Strontium carbonate			Trace		
Iron carbonate	0.54			2.40	
Sodium sulphate		4.29		4.51	8.82
Calcium sulphate				74.21	81.94
Magnesium sulphate				12.00	17.07
Potassium sulphate	0.27	2.08	2.13		
Sodium hyposulphite		0.32	3.74		
Sodium phosphate		0.01	Trace		
Calcium phosphate	0.01				
Sodium biborate		Trace			
Sodium sulphide			7.13		
Sodium bisulphide		5.86			
Iron sulphide (in suspension)		Trace	Trace		
Sodium chloride	0.16	12.93	1.01	1.96	
Magnesium chloride					0.10
Calcium chloride					0.14
Lithium chloride		0.06			
Sodium iodide		Trace			
Sodium bromide		Trace			
Aluminium oxide		0.29	Trace	0.50	
Iron oxide					1.19
Silica	1.38	0.50	1.46		Trace
Iodine			Trace		
Bromine			Trace		
Organic matter					0.04
Total	20.73	43.75	30.25	108.84	109.30
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen		1.16	1.17		
Carbon dioxide	14.64	14.26	14.75		

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[a] N. T. Lupton, analyst (1880).
[b] J. M. Safford, analyst.
[c] J. M. Safford, analyst (1884).
[d] J. B. Mitchell, analyst.
[e] J. R. Chilton, analyst.

Analyses of mineral springs in Tennessee—Continued.

Constituents.	Raleigh Mineral Springs.					
	Beach Spring.	Box Spring.	Freestone Spring.	Magnolia Spring.	Marble Spring.	Bayless Spring.
	Grams in 10,000.[a]	*Grams in 10,000.*[a]	*Grams in 10,000.*[a]	*Grams in 10,000.*[b]	*Grams in 10,000.*[a]	*Grams in 10,000.*[b]
Calcium carbonate		0. 201		0. 580	0. 060	0. 306
Magnesium carbonate				0. 264	Trace.	0. 097
Magnesium bicarbonate		0. 044	0. 143			
Iron protocarbonate	0. 421	0. 296	0. 042	0 631	0. 193	1. 182
Sodium sulphate		0. 142		0. 060	0. 214	0. 525
Calcium sulphate			0. 175			
Magnesium sulphate				0. 070		0. 037
Potassium sulphate		0. 077			0. 356	
Aluminium sulphate	[c]Trace	0. 153			0. 086	
Sodium chloride	0. 275	0. 190	0. 132	0. 102	0. 146	0. 190
Magnesium chloride	0. 083		0. 003			
Calcium chloride	0. 235		0. 135			
Potassium chloride	0. 015		0. 078			
Aluminium oxide				(c)		(d)
Silica				0. 262		0. 377
Carbonic acid (free)	2. 003	1. 793	1. 005	2. 887	0. 450	2. 491
Organic matter			[e] Present	0. 337		0. 709
Total	3. 032	2. 896	1. 718	5. 202	1. 505	5. 914

Constituents.	Primm's Springs: Spring No. 2.	Red Boiling Springs.	Rhea Springs.	Tate's Epsom Spring.	Tilford's Mineral Well.
	Grains per gallon.[f]	*Grains.*[g]	*Parts in 1,000,000.*[h]	*Grains per gallon.*[i]	*Grains per gallon.*[j]
Sodium carbonate					22. 59
Calcium carbonate	0. 85	26. 00		21. 56	0. 62
Magnesium carbonate	0. 91				0. 17
Lithium carbonate					Trace
Iron bicarbonate			616		
Sodium sulphate	5. 22		513	8. 50	6. 23
Calcium sulphate	32. 87	6. 00	600	160. 66	
Magnesium sulphate	29. 81	8. 00	234	81. 91	
Potassium sulphate	1. 72			1. 54	0. 39
Iron protosulphate	Trace				
Sodium hyposulphite					1. 02
Sodium phosphate					Trace
Calcium phosphate				1. 14	
Magnesium phosphate	2. 10				
Sodium biborate					Trace
Sodium sulphide Magnesium sulphide	2. 57				0. 45
Sodium chloride	5. 48	1. 00	23	40. 27	4. 49
Manganese chloride				0. 66	
Iron chloride				2. 92	
Sodium iodide				Trace	
Aluminium oxide					0. 06
Iron protoxide		2. 50			
Silica		1. 50		2. 70	0. 15
Nitric acid				0. 02	
Carbonic acid (free)		15. 00			
Iodine					Trace
Bromine					Trace
Organic matter			91		
Total	81. 53	60. 00	20. 77	271. 88	36. 16
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbon dioxide			Large am't	Present	14. 00
Sulphureted hydrogen		4. 50			Trace
Carbureted hydrogen					Present

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[a] Enno Sander, analyst (1886).
[b] Theodore Hoerner, analyst.
[c] Traces of silicate and phosphate of alumina.
[d] Traces of silicate of alumina.
[e] Traces of nitrogen.
[f] A. B. Raine, analyst (1879).
[g] J. M. Safford, analyst.
[h] William Baker, analyst.
[i] T. S. Antisell, analyst (1872).
[j] J. M. Safford, analyst (1884).

Analyses of mineral springs in Tennessee—Continued.

Constituents.	West Nashville Sulphur Well.	White Cliff Springs.	White Creek Springs.	West End Mineral Water, Nashville.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Sodium carbonate	9.26			19.18
Calcium carbonate	13.21		35.42	2.272
Calcium bicarbonate		1.47		
Magnesium carbonate	5.06			5.144
Magnesium bicarbonate		2.89		
Potassium carbonate				1.040
Lithium carbonate	Trace			Trace
Iron bicarbonate		1.93		
Sodium sulphate	14.31		13.20	
Calcium sulphate		1.51	19.64	15.304
Magnesium sulphate			19.32	
Potassium sulphate	2.14			
Sodium hyposulphate			6.50	
Sodium sulphide	11.85			16.368
Sodium chloride	66.65	0.92		66.272
Potassium chloride		0.56		
Aluminium oxide Iron oxide	0.07	0.08		.072
Silica		1.12		
Iodine	Trace			Trace
Bromine	Trace			Trace
Total	122.55	10.48	94.08	125.656
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbon dioxide			37.996	
Sulphureted hydrogen	5.840		40.25	0.730

[a] N. T. Lupton, analyst (1888).
[b] Troost, analyst (1841).
[c] N. T. Lupton, analyst (1884).

KENTUCKY.

The State of Kentucky occupies a prominent place as a mineral spring region, not only from the number of springs, but also on account of the quality of the waters. Some of them are among the most remarkable in the country and many are on sale in the East, West, North, and South. Such are the celebrated Blue Lick water and that of the Crab Orchard springs. There are said to be two great water beds in Kentucky, viz: the calciferous sandstone, underlying the Silurian rocks, and the great sandstone formation at the base of the Coal Measures, and any localities in counties within the range of those formations (Silurian and Carboniferous), if not already possessed of mineral springs, can have artesian mineral wells by boring from 150 to 300 feet. Still the mineral waters do not appear to be confined to these beds, although possibly more abundant in them. Our list mentions springs as occurring in nearly two-thirds of the counties, and the remaining counties are not confined to any one portion of the State; so that it is possible that, if the information relating to them were more complete, they also might be included among those having mineral springs.

The great majority of the springs are still unimproved, although many are used as local resorts, especially during the summer season. The reports of the Kentucky geological survey are quite complete in the description of the mineral springs of the State, and Dr. Peters's chemical reports on them have furnished a large proportion of the analyses given in the tables in this paper. Davies's report on the resources of the State has also furnished considerable data.

Mineral springs of Kentucky.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Allen Springs, Allen Springs, Warren County.	......	......	......	Sulphureted	Resort.
Alum Springs, near Esculapia Springs, Lewis County.	......	......	......	......	
Alum Springs, base of Burdett's Knob, Boyle County.	......	......	......	Chalybeate	
Beachville Springs, Beachville, Metcalfe County.	2	......	......	Saline and sulphureted.	Local resort.
Bedford Springs, Bedford, Trimble County.	3	60	......	Saline	Used commercially and as a resort.
Big Bone Lick Springs, Big Bone Lick, east of Hamilton, Boone Co.	3	......	......	Saline, sulphureted.	
Big Lick Springs, Gallatin County ..	......	......	......	... do	
Blue Lick Spring (lower), Blue Lick Springs, Nicholas County.	1	300	62	Saline	Do.
Blue Lick Spring (upper), Davidson, Nicholas County.	1	1,200	60	Sulpho-saline ...	Used commercially.
Box Mountain Sulphur Springs, 4 miles west of Morton's Gap, Hopkins County.	....	......	63	Sulphureted	
Brown Spring, near Crab Orchard, Lincoln County.	......	......	......	......	
Bryant's Springs, near Crab Orchard, Lincoln County.	6	......	......	Chalybeate and saline sulphureted.	
Buena Vista Springs, northwest of Russellville, Logan County.	......	......	......	......	
Buffalo Springs, 15 miles southwest of Big Spring, Breckinridge Co.	......	......	......	Sulphureted	
Burgher's Spring, near Russellville, Logan County.	1	30	55	Chalybeate	Resort.
Campbellsville Sulphur Spring, Campbellsville, Taylor County.	......	......	......	Saline, sulphureted.	
Cerro Gordo Springs, near Russellville, Logan County.	......	......	......	......	
Cerulean Springs, Cerulean Springs, north of Wallonia, Trigg County.	......	60	56	Saline	
Chalybeate springs:					
Near Letcher Court-House, Letcher County.	......	......	......	......	
Southeast of Morganfield, Union County.	......	......	......	......	
In Bath County..........	......	......	......	......	
In Bell County	......	......	......	......	
In Breathitt County	......	......	......	......	
In Bullitt County	......	......	......	......	
In Hancock County	......	......	......	......	
Four miles southwest of Hickman (Combs), Fulton County.	......	......	......	......	
In Pulaski County	......	......	......	......	
Near Eminence, Henry County ..	......	......	......	Saline, chalybeate.	
In Perry County..........	......	......	......	......	
In Jackson County	......	......	......	......	
In Johnson County..........	......	......	......	......	
Near Cumberland Falls, Whitley County.	2	......	......	Carbonated, chalybeate.	
Chalybeate and Saline Springs, on Barnett's Creek, Ohio County.	......	......	......	......	
Chameleon Springs, south of Brownsville, Edmonson County.	......	......	......	Sulphureted	
Clear Creek Sulphur Springs, near Pineville, Bell County.	......	......	......	......	

Mineral springs of Kentucky—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Crab Orchard Springs, Crab Orchard, Lincoln County.					Resort, and the evaporated salts used commercially.
Creel White Sulphur Spring, Marion County.				Saline, sulphureted.	
Crittenden Spring, Crittenden Co.	1	75	61	Saline, carbureted.	
Davis Spring or Well, 5 miles northeast of Morton's Gap, Hopkins Co.	1			Saline, chalybeate.	Resort.
Drennon Springs, Drennon Springs, south of Port Royal, Henry County.				Saline, sulphureted.	Once a resort.
Dripping Springs, Garrard County, 2 miles east of Crab Orchard.	5	400	55 to 56	Saline, chalybeate.	Resort.
Elliston's Sulphur Spring, Madison County.				Saline, sulphureted.	
Epsom Spring, near Crab Orchard, Lincoln County.					
Epsom Spring, near Bedford, Trimble County.					
Esculapia Springs, Esculapia Springs, Lewis County.	8		55	Chalybeate, sulphureted, &c.	Do.
Estill Springs, near Irvine, Estill County.				Saline, sulphureted.	
Foley's Epsom Spring, near Crab Orchard, Lincoln County.					
Fox Springs, 10 miles from Flemingsburg, Fleming County.	6			Sulphureted	Do.
Grayson Springs, Grayson Springs, Grayson County.	100+	2, 800+	58 to 67	do	Used commercially and as a place of resort.
Grigsby's (R. B.) White Sulphur Mineral Spring, Nelson County.				Saline, sulphureted.	
Hardin Spring, Hardin Springs, Hardin County.	1	275		Sulphureted	Resort.
Hardinsville Sulphur Springs, Hardinsville, Shelby County.				do	
Harrodsburg Springs, Harrodsburg, Mercer County.				Saline	
Hickman's Springs, south of Owensborough, Crow's Station, Daviess County.	6			Chalybeate, saline, and sulphureted.	
Howard's Sulphur Well, near Crab Orchard, Lincoln County.					
Howell Mineral Springs, Hardin County.				Saline, chalybeate.	
Indian Spring, near Jones's Mill, Grayson County.					
Innis Sulphur Well, 7 miles north of Lexington, Fayette County.				Saline, sulphureted.	
James Mineral Spring, near Springfield, Washington County.				do	
Jesse's Mineral Well, near Versailles, Woodford County.				Sulphureted	
Kentucky Alum Springs, Boyle County, 92 miles from Louisville.	8				Used commercially.
Kirk Spring, Lewis County					
Kuttawa Mineral Springs, near Kuttawa, Lyon County.	4	1, 200	62	Alkaline, carbonated.	Has local reputation.
Latonia Springs, 4 miles from Covington, Kenton County.	5			Sulphureted, saline.	Resort.
Lexington Mineral Well, Lunatic Asylum, Lexington, Fayette Co.				Saline, sulphureted.	
Linsey's Mineral Spring, Christian Co.			71	Sulphureted	
Louisville (Dupont's) Artesian Well, Louisville, Jefferson County.	1			Saline	
Mammoth Well, Nelson County					
Milldale Mineral Well, Milldale, Kenton County.				Saline, sulphureted.	
Miller's Mineral Well, near Barboursville, Knox County.				Saline	
Mineral springs:					
At Slick Rock, Barren County					
In Menifee County					
In Martin County					

Mineral springs of Kentucky—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Mineral springs—Continued.			°		
At railroad crossing, Green River, Lincoln County.	......	......	......	Saline, sulphureted.	Resort.
In Lee County	......	......	......	......	
In Marshall County	......	......	......	......	
On Kettle Creek, Cumberland Co.	......	......	......	......	
In Robertson County	......	......	......	......	
At Allen Springs, Warren County	......	......	......	......	
In Floyd County	......	......	......	Weak	
At Harmony, Owen County	......	......	......	Saline	
In Henderson County	......	......	......	......	
At copper mine, near Irvine, Estill County.	......	......	......	Saline	
In La Rue County	......	......	......	......	
Near New Concord, Calloway Co.	......	......	......	......	
In Carter County	......	......	......	......	
In Clay County	......	......	......	......	
In Pendleton County	......	......	......	......	
In Powell County	......	......	......	......	
Two miles from Downingsville, Grant County.	......	......	......	......	
Mineral wells:					
At Walnut Hill, Fayette County.	......	......	......	Saline, sulphureted.	
At Paint Lick, Garrard County	......	......	......	Saline	
Near Crab Orchard, Lincoln Co	......	......	......	Sulphureted	
At Smith's Grove, Warren Co	......	......	......	Saline, sulphureted.	
At Dr. J. Read's, Madison County.	......	......	......	Sulphureted	
Two miles west of Nicholasville, Jessamine County.	......	......	......	Saline, sulphureted.	
Mixed Spring, ½ mile from Dripping Springs, Lincoln County.	1	200	56	Saline, chalybeate.	Do.
Murray's Springs, near Lewis, Daviess County.	......	......	......	...do	
Nevien's Sulphur Springs, sources of Salt River, Lincoln County.	....	......	......	Saline, sulphureted.	
Oliver Springs, Daviess County	......	......	......	......	
Olympian Springs, Olympia, Bath Co.	10+	......	54 to 62	Saline, sulphureted.	
Paroquet Springs, near Shepherdsville, Bullitt County.	......	......	......	...do	Do.
Pollard's Mineral Well, near Crab Orchard, Lincoln County.	1	......	......	Sulphureted	
Robb's Chalybeate Spring, on Massack Creek, McCracken County.	1	......	......	Chalybeate	
Rockcastle Spring, Rockcastle Springs, Pulaski County.	1	25	......	...do	Do.
Rochester Springs, Boyle County, 17 miles from Harrodsburg.	......	......	......	Saline	
Rough Creek Springs, Grayson Co	......	......	......	......	
Russell Sulphur Springs, Russell Co.	2	......	......	......	
Salt Sulphur, Bath County	......	......	......	......	
Salt Sulphur Well, Nicholasville, Jessamine County.	......	......	......	Saline, sulphureted.	
Salubrian Springs, 8 miles southeast of Hopkinsville, Christian County.	2	60	50	Sulphureted	Local resort.
Sebree Springs, near Sebree, Webster County.	2+	......	......	Saline, sulphureted, and chalybeate.	Resort.
Social Hill Mineral Spring, at Judge Eaves's, Muhlenberg County.	......	......	......	Sulphureted	
Sowder's Spring, near Crab Orchard, Lincoln County.	......	......	......	......	
St. Bernard Springs, ½ mile northwest of Morton's Gap, Hopkins County.	......	......	......	......	
Sudduth or Mud Spring, Mud Lick, Bath County.	......	......	......	......	
Sulphur springs:					
At Sinking Spring, 7 miles from Big Spring, Breckinridge Co.	......	......	......	......	
In Hancock County	......	......	......	......	
One mile east of Clear Spring, Graves County.	......	......	......	......	

Mineral springs of Kentucky—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Sulphur springs—Continued.			°		
In Union County					Resort.
In Jackson County					
In Johnson County					
In Breathitt County					
In Livingston County			59	Saline, chalybeate.	
On Doe Run, southeast of Brandenburg, Meade County.					
Southeast of Morganfield, Union County.					
Southwest of Jeffersonville, Montgomery County.					
Sulphur Mineral Well, Fleetwood farm, near Frankfort, Franklin Co.				Saline, sulphureted.	
Swinney's Chalybeate Spring, 1½ miles from Chameleon Springs, Edmonson County.				Chalybeate	
Taliaferro Springs, 1½ miles southwest of Morton's Gap, Hopkins Co.				Chalybeate	
Tar Springs, south of Cloverport, Breckinridge County.				Saline	
Trice's Salt Sulphur Well, Hopkinsville, Christian County.					
Washington Bell's Sulphur Spring, on Sulphur Lick Creek, Nelson Co.	1				Do.
White Sulphur Mineral Spring, Marion County.					
White sulphur springs:					
At Cloverport, Breckinridge Co				Saline, sulphureted.	
In Ohio County					Do.
White Sulphur Well, Sulphur Well, Metcalfe County.					
Williams's Mineral Well, near Versailles, Woodford County.	1			Saline	
Wilson's Saline-Chalybeate Spring, Lexington, Fayette County.				Alkaline	
Yates Mineral Spring, near base of Knob Lick, Boyle County.				Saline	
Yelvington Spring, Yelvington, Daviess County.					
Young's Springs, Young's Springs, Bath County.	3	58	57 to 62	Sulphureted	Do.

Analyses of mineral springs in Kentucky.

Constituents.	Bryant's Springs.					
	Chalybeate Fountain.	Knob Spring.	Pasture Spring.	Stone's Sulphur Spring.	Valley Spring.	Well.
Solids.	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]
Calcium carbonate	0. 12		0. 09	0. 06	0. 09	0. 48
Magnesium carbonate	0. 02		0. 04	0. 12	0. 05	0. 01
Iron carbonate	0. 01	Trace	0. 02	0. 02	Trace	0. 02
Sodium sulphate		0. 21				0. 02
Potassium sulphate	0. 01	0. 02	0. 03	0. 01	0. 02	0. 07
Calcium sulphate		0. 10	0. 01	0. 01	Trace	0. 97
Magnesium sulphate	0. 03	0. 07	0. 07	0. 02	0. 01	0. 90
Sodium chloride	0. 09	0. 93	0. 02	Trace	0. 18	0. 28
Magnesium chloride					0. 04	
Silica	0. 01	0. 01	0. 04	0. 03	0. 01	0. 09
Total	0. 29	1. 34	0. 32	0. 27	0. 40	2. 84

[a] Robert Peter, analyst.

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Crab Orchard Springs.		Blue Lick Spring (Upper).	Chalybeate Springs near Cumberland Falls.	
	Field Spring.	Grove Spring.		North Side River.	South Side River.
Solids.	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]	*Grains per gallon.*[b]	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]
Calcium carbonate	0. 14	0. 10	25. 06	0. 05	0. 04
Magnesium carbonate	0. 13	0. 04	0. 14	0. 03	0. 03
Manganese carbonate	0. 01	0. 01		0. 01	0. 01
Iron carbonate		0. 02			
Sodium sulphate	0. 02				
Potassium sulphate	0. 02	0. 01	12. 97		
Calcium sulphate			44. 13	0. 01	Trace
Magnesium sulphate	0. 07	0. 06		[c]0. 01	0. 01
Iron sulphate				Trace	[d]0. 01
Calcium phosphate			[d]1. 97		
Sodium chloride	0. 01	0. 01	516. 54	Trace	Trace
Potassium chloride			1. 80	Trace	Trace
Magnesium chloride			37. 72		
Magnesium bromide			8. 80		
Magnesium iodide			0. 16		
Silica	0. 04	0. 04	1. 00	0. 03	0. 01
Nitric acid		Trace			
Loss			14. 88	0. 04	0. 01
Total	0. 44	0. 38	660. 17	0. 18	0. 12
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen			10. 24		
Carbonic acid			60. 11		

Constituents.	Estill Springs.				
	Red Sulphur Spring, near saloon.	White Sulphur Spring.	Red Sulphur Spring.	Black Sulphur Spring.	Chalybeate Spring.
Solids.	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]
Sodium carbonate	0. 02	0. 08			
Calcium carbonate	0. 20	0. 30	0. 02	0. 11	0. 16
Magnesium carbonate	0. 08	0. 01	0. 02	0. 03	0. 05
Iron carbonate			Trace	0. 07	0. 03
Sodium sulphate	0. 17	0. 04		0. 03	0. 01
Potassium sulphate	0. 09	0. 07	0. 01	0. 02	0. 01
Calcium sulphate					0. 28
Magnesium sulphate	0. 01	0. 11	0. 04	0. 02	0. 17
Aluminium sulphate				0. 62	
Sodium chloride	0. 09	0. 01	0. 10	0. 04	0. 01
Calcium chloride			0. 11		
Alumina		[e]0. 02			[e]Trace
Silica	0. 01	Trace	0. 03	0. 01	0. 03
Organic matter	0. 04	0. 05	0. 04	0. 06	0. 14
Total	0. 71	0. 69	0. 37	0. 41	0. 89
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen	0. 0045	0. 003	0. 012	0. 035	
Carbonic acid	0. 3256	0. 360	0. 228	0. 263	0. 269

[a] Robert Peter, analyst.
[b] J. F. Judge and A. Fennel, analysts (1870).
[c] With aluminium sulphate.
[d] With alumina and peroxide of iron.
[e] With trace of phosphates.

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Epsom Spring, near Crab Orchard.	Foley's Epsom Spring.	Sebree Springs.		
			Sulphur Spring.	Chalybeate Spring.	Korb Spring.
Solids.	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]	*Grains in 1,000.*[b]	*Grains in 1,000.*[b]	*Grains per gallon.*[c]
Calcium carbonate	0.67	0.91	0.218	0.025	1.21
Magnesium carbonate	0.12	0.18	0.050	0.018	12.45
Manganese carbonate	....	....	....	Trace	....
Iron carbonate	Trace	Trace	....	0.030	2.77
Sodium sulphate	0.77	1.01	0.148	0.020	....
Potassium sulphate	0.07	0.17	0.004	0.004	....
Calcium sulphate	0.20	0.19	0.062	0.022	11.72
Magnesium sulphate	3.45	3.52	0.057	....	....
Sodium chloride	0.08	0.30	0.276	0.003	2.80
Iron oxide	....	....	....	....	4.38
Silica	0.06	0.06	0.017	0.001	....
Organic matter	....	....	0.008	0.006	....
Loss	....	0.59	....	....	....
	5.42	6.88	0.835	0.129	35.33

Constituents.	Blue Lick Spring (Lower).		Brown Spring.	Grayson Springs.
				Center Spring.
Solids.	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]	*Grains in 1,000.*[a]
Sodium carbonate	....	0.0140	....	....
Calcium carbonate	0.3850	0.3184	0.12	0.17
Magnesium carbonate	0.0022	0.0211	0.02	Trace
Manganese carbonate	....	....	Trace	Trace
Iron carbonate	[d]0.0058	[d]0.0038	0.03	
Potassium sulphate	0.1519	....	0.08	....
Calcium sulphate	0.5583	0.5508	0.02	1.17
Magnesium sulphate	....	....	0.11	0.58
Aluminium sulphate	....	....	....	[e] Trace
Strontium sulphate	....	0.0011	....	....
Barium sulphate	....	0.0002	....	....
Manganese sulphate	....	....	....	[d]Trace
Iron sulphate	....	....	....	
Sodium biborate	....	0.0298	....	....
Sodium chloride	8.3473	8.3571	0.02	....
Calcium chloride	....	0.0606	....	....
Potassium chloride	0.0227	0.1860	....	....
Lithium chloride	....	0.0060	....	....
Magnesium chloride	0.5272	0.4864	....	0.19
Magnesium bromide	0.0039	0.0195	....	....
Magnesium iodide	0.0007	0.0003	....	....
Sodium sulphide	....	0.0307	....	0.06
Potash	....	....	....	Trace
Soda	....	....	....	Trace
Silica	0.0179	0.0149	0.04	Trace
Lithium	....	....	....	Traces
Iodine	....	....	....	
Bromine	....	....	....	
Organic matter	0.2821	0.4573	0.05	Trace
Loss				
Total	10.3000	10.5580	0.44	2.17
Gases.				
Sulphureted hydrogen	0.3947	Undeterm'd	....	0.0200
Carbonic acid	0.3547	....do	....	0.1950

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[a] Robert Peter, analyst (1850).
[b] A. M. Peter, analyst (1877).
[c] E. S. Wayne, analyst (1884).
[d] With alumina and calcium phosphates.
[e] With phosphates.

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Grayson Springs.				
	McAtee Spring.	Moreman Spring.	Jar Spriug.	Eye Spring.	Stump Spring.
Solids.	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]
Calcium carbonate	0.18	0.20	0.16	0.19	0.20
Magnesium carbonate	Trace	0.05	0.03	Trace	Trace
Manganese carbonate	0.01	0.01	0.01	0.01	0.01
Iron carbonate					
Sodium sulphate	0.02	...	...	0.02	0.04
Potassium sulphate	Trace	...	Trace	Trace	Trace
Calcium sulphate	0.45	0.45	0.51	0.67	0.63
Magnesium sulphate	0.46	0.38	0.58	0.75	0.61
Manganese sulphate	[b]0.02	[b]Trace	[b]Trace	[b]Trace	...
Iron sulphate					
Sodium chloride	0.02	...	0.08	0.11	Trace
Magnesium chloride	...	0.02	...	...	Trace
Sodium sulphide	...	0.04	0.02	0.01	...
Potash	...	Trace	...	...	...
Soda	...	0.01	...	...	...
Silica	Trace	Trace	Trace	0.01	Trace
Lithium	Traces	Traces	...	...	...
Iodine			...	...	...
Bromine			...	...	...
Organic matter	Trace	...	0.23	0.03	0.02
Total	1.16	1.16	1.62	1.80	1.51
Gases.					
Sulphureted hydrogen	0.0203	0.0248	0.0265	0.0239	0.0410
Carbonic acid	0.1500	0.1234	0.2020	...	0.1650

Constituents.	Grayson Springs.					
	White Sulphur.	Hymeneal Spring.	Rock Spring.	Artesian Well.	Chalybeate well at Springs.	Chalybeate well near Springs.
Solids.	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]	*Grains in* 1,000.[a]
Calcium carbonate	0.18	0.15	0.17	0.14	0.12	0.26
Magnesium carbonate	Trace	([c])	0.01	0.02	Trace	Trace
Manganese carbonate	0.01	...	0.01	0.01	0.01	0.08
Iron carbonate		...				
Sodium sulphate	...	...	0.03	...	Trace	1.13
Potassium sulphate	...	0.01	Trace	...	Trace	0.06
Calcium sulphate	0.65	0.90	0.59	1.30	0.01	2.33
Magnesium sulphate	0.65	0.88	0.47	0.88	Trace	0.74
Manganese sulphate	[b]Traces	[b]Traces	[d]Traces	Traces	...	...
Iron sulphate					...	...
Sodium chloride	0.02	0.02	0.01	0.30	0.01	0.15
Potassium chloride	...	...	...	...	0.01	...
Sodium sulphide	0.02	0.02	Trace	0.03	...	...
Silica	0.03	...	0.01	0.08	Trace	0.03
Organic matter	0.18	...	0.15	Trace	...	...
Total	1.74	1.90	1.45	2.71	0.16	4.78
Gas.						
Sulphureted hydrogen	0.0270	...	...	0.0330	...	...

[a] Robert Peter. [b] With phosphates. [c] Not estimated. [d] With alumina, sulphate, and phosphates.

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Harrodsburg Springs.		Howard's Sulphur Well.	Kentucky Alum Springs.	Elliston's Sulphur Spring.	Indian Spring.
	Saloon Spring.	Grenville Spring.				
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains in 1,000.*[b]	*Grains per gallon.*[c]	*Parts in 1,000.*[b]	*Grains in 1,000.*[b]
Sodium carbonate					0.10	
Calcium carbonate	23.92	4.80	0.01		0.20	0.01
Magnesium carbonate	2.08	22.96	0.07		0.03	Trace
Manganese carbonate						[e] 0.01
Iron carbonate	2.88				[d] 0.02	
Sodium sulphate						Trace
Potassium sulphate			0.01	Trace		Trace
Calcium sulphate	81.92	88.48		4.76	0.43	0.07
Magnesium sulphate	223.36	129.28	0.01	0.97		Trace
Aluminium sulphate				40.26		
Ammonium sulphate				Trace		
Manganese sulphate				Trace		
Iron sulphate				1.71		
Iron persulphate				14.39		
Sodium chloride	9.92	Trace	0.02	0.53	0.32	0.04
Calcium chloride					0.01	
Potassium chloride					0.04	Trace
Magnesium chloride					0.09	
Sodium sulphide					Trace	
Alumina			Trace			
Silica			0.02	3.50	0.01	0.01
Strontium					Trace	
Lithium					Trace	
Organic matter					0.33	
Phosphoric acid				Trace		
Loss			0.02			
Total	349.08	245.52	0.16	66.12	1.58	0.14

Constituents.	Hickman's Springs.					
	No. 1. Alum Spring.	No. 2. Alum Spring.	No. 3. Sulphur Spring.	No. 4. Brick Spring.	No. 5. Yellow Spring.	No. 6. Sweet Spring.
Solids.	*Grains in 1,000.*[b]	*Grains in 1,000.*[b]	*Grains in 1,000.*[b]	*Grains in 1,000.*[b]	*Grains in 1,000.*[b]	*Grains in 1,000.*[b]
Calcium carbonate			0.11	0.12	0.03	
Magnesium carbonate			0.02	0.03	0.02	
Sodium sulphate	0.07	0.30	0.46	0.50	0.21	
Potassium sulphate	Trace	0.01	Trace	0.01	0.01	0.01
Calcium sulphate	0.60	0.39	0.13	0.08	0.14	0.33
Magnesium sulphate	0.33	0.33	0.16	0,11	0.07	0.25
Aluminium sulphate	1.25	0.33				0.35
Manganese sulphate	Trace	0.01				0.07
Iron persulphate	0.88	0.05				0.15
Copper sulphate	Trace				Trace	
Sodium chloride	Trace	0.01	0.08	0.02	0.01	0.06
Iron oxide			[f] Trace	[f] Trace	[f] Trace	
Silica	Trace	Trace	0.02	0.03	0.03	Trace
Lithium	Trace	Trace	Trace	Trace	Trace	Trace
Organic matter		0.03	0.04		0.03	0.19
Total	3.13	1.46	1.02	0.90	0.55	1.41

[a] Raymond, analyst.
[b] Robert Peter, analyst.
[c] Dr. L. D. Kastenbine, analyst.
[d] With phosphoric acid.
[e] With phosphates and alumina.
[f] With manganese oxide.

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Louisville Artesian Well.	Milldale Mineral Well.	Mineral Well, Smith's Grove.	Sulphur Well near Frankfort.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains in 1,000.*[c]	*Grains in 1,000.*[c]
Sodium carbonate			0.04	0.04
Sodium bicarbonate	2.78			
Calcium carbonate			0.15	0.25
Calcium bicarbonate	5.90			
Magnesium carbonate		1.20	0.02	Trace
Magnesium bicarbonate	2.76			
Strontium carbonate			Trace	
Iron bicarbonate	0.85			
Sodium sulphate	72.80		0.02	
Potassium sulphate	8.22		Trace	
Calcium sulphate	29.48	1.22	0.10	0.11
Magnesium sulphate	77.34		0.29	
Aluminium sulphate	1.80			
Sodium phosphate	1.54			
Sodium chloride	621.58	509.26	0.05	0.05
Calcium chloride	65.73	11.26		0.03
Potassium chloride	4.22	0.62		0.01
Lithium chloride	0.10		Not estimated	
Magnesium chloride	14.78	8.42		0.02
Aluminium chloride	1.21			
Magnesium bromide	0.47			
Magnesium iodide	0.35			
Silica	0.80		Trace	Trace
Organic matter	0.71			
Phosphoric acid				Trace
Nitric acid				Trace
Loss	8.12		0.25	
Total	915.57	531.98	0.92	0.51
Gases.		*Cubic inches.*		
Sulphureted hydrogen	2.01	0.78		
Carbonic acid	6.17			
Nitrogen	1.36			

Constituents.	Murray's Springs.	Paroquet Springs.	Pollard's Mineral Well.	Mineral Spring near Irvine.
Solids.	*Grains in 1,000.*[c]	*Grains per gallon.*[a]	*Grains in 1,000.*[d]	*Grains in 1,000.*[c]
Sodium carbonate		0.38	0.02	
Calcium carbonate	0.12	2.40	0.14	0.53
Magnesium carbonate	0.01	1.50	0.15	0.04
Manganese carbonate				0.02
Iron carbonate	0.02	0.18		
Sodium sulphate	0.05	2.41		
Potassium sulphate	0.04		0.07	0.04
Calcium sulphate	0.02	2.28	Trace	0.55
Magnesium sulphate	0.08			4.52
Aluminium sulphate		0.49		
Sodium chloride	0.01	309.60	0.69	0.30
Calcium chloride		67.71		0.08
Potassium chloride		0.48	0.02	
Lithium chloride	Trace			
Magnesium chloride		48.08	0.12	
Magnesium bromide		0.31		
Sodium bromide		0.18		
Sodium iodide		0.16		
Magnesium iodide		0.25		
Alumina	Trace			
Silica	0.02	3.90	0.01	0.07
Organic matter		2.14		
Phosphoric acid	Trace			
Loss				1.47
Total	0.37	442.40	1.22	7.57
Gases.		*Cubic inches.*		
Sulphureted hydrogen		0.30		
Carbonic acid		0.06		

[a] J. Lawrence Smith, analyst.

[b] E. S. Wayne, analyst.

[c] Robert Peter, analyst.

[d] Robert Peter, analyst (1861).

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Olympian Springs.			
	Salt Sulphur Spring.		Black Sulphur Spring.	
Solids.	*Parts* in 1,000.[a]	*Parts* in 1,000.[b]	*Parts* in 1,000.[a]	*Parts* in 1,000.[b]
Sodium carbonate	(c)	(c)	0.254	0.3247
Calcium carbonate	0.230	0.1975	0.114	0.0158
Magnesium carbonate	0.124	0.0506	0.006	0 0046
Strontium carbonate		0.0045		
Manganese carbonate		[d]Trace		[d]Trace
Iron carbonate	Trace	0.0025	Trace	0.0024
Barium carbonate		0.0128		
Sodium sulphate				0.0025
Potassium sulphate			0.002	0.0031
Calcium sulphate	Trace	0.0083		0.0061
Magnesium sulphate			0.012	
Sodium chloride	2.847	4.8997	0.127	0.1218
Calcium chloride		0.0218		
Potassium chloride	0.183	0.0356		
Lithium chloride		0.0008		Trace
Magnesium chloride	0.950	0.1089		
Sodium bromide		0.0166		
Sodium iodide		Trace		Trace
Sodium sulphide		Trace		Trace
Alumina	Trace	0.0006		
Silica	0.018	0.0282	0.048	0.0124
Iodine	Trace			
Bromine	Trace			
Boracic acid		Trace		Trace
Phosphoric acid		Trace		Trace
Loss and organic matter	1.348	0.0340		0.0164
Total	54.708	5.4168	0.558	0.5098
Gases.				
Sulphureted hydrogen	Present	0.0011	Present	0.0012
Carbonic acid	0.318	0.2400		0.2781

Constituents.	Olympian Springs.			
	White Sulphur Spring.	Main Chalybeate Spring.	Main Chalybeate Spring.	Chalybeate. Spring.
Solids.	*Parts* in 1,000.[e]	*Grains* in 1,000.[b]	*Grains* in 1,000.[a]	*Grains* in 1,000.[e]
Sodium carbonate	0.3118			
Calcium carbonate	0.0744	0.0998	0.101	0.0890
Magnesium carbonate	0.0316	0.0143	0.022	0.0103
Manganese carbonate		Trace		Trace
Iron carbonate		0.0242	(c)	0.0100
Sodium sulphate	0.0408			0.0238
Potassium sulphate	0.0133	0.0125	0.070	0.0117
Calcium sulphate	0.0039	0.0554	0.020	0.0366
Magnesium sulphate		0.1170	0.021	0.0693
Sodium chloride	0.1326	0.0308	0.035	0.0060
Lithium chloride	Trace	Trace		Trace
Magnesium chloride	0.0071	0.0031		
Sodium bromide	Trace			
Sodium iodide	Trace			
Sodium sulphide	Trace			
Alumina	[f]0.0021			
Silica	0.0115	0.0332	0.107	0.0198
Apocrenic acid		Trace		Trace
Boracic acid	Trace			
Phosphoric acid	Trace	Trace		Trace
Loss		0.0194		0.0168
Total	0.6286	0.4097	0.376	0.2933
Gases.				
Hydrogen sulphide	(c)			
Carbonic acid	(c)	0.1214	Present	0.1269

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[a] Robert Peter, analyst (1861).
[b] Robert Peter, analyst (1880).
[c] Not estimated.
[d] With phosphoric acid.
[e] Robert Peter, analyst.
[f] With iron and manganese carbonates.

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Olympian Springs.				
	Salt Lick.	Epsom Well.	Tea Spring.	Kitchen Well.	
	Pts. in 1,000.[a]	*Pts. in* 1,000.[a]	*Grs. in* 1,000.[b]	*Pts. in* 1,000.[c]	*Pts. in* 1,000.[d]
Sodium carbonate	0.23	....	0.45	0.54	Trace
Calcium carbonate	0.18	0 63	0.02	0.05	0.19
Magnesium carbonate	0.05	0.22	0.01	0.03	0.10
Strontium carbonate	Trace	....	Trace	Trace	....
Manganese carbonate	[e]Trace	....	Trace	[e]0.01	....
Iron carbonate	[e]Trace	Trace	Trace		Trace
Barium carbonate	0.01	....	....	....	....
Sodium sulphate	....	1.36	....	0.02	....
Potassium sulphate	....	0.04	....	0.03	0.27
Calcium sulphate	Trace	0.58	....	0.01	0.01
Magnesium sulphate	....	2.60	....	....	....
Strontium sulphate	....	....	Trace	....	....
Iron sulphate	....	Trace	....	....	....
Sodium chloride	4.71	0.83	0.04	0.15	4.25
Calcium chloride	0.02	....	....	....	....
Potassium chloride	0.04	....	Trace	....	0.06
Lithium chloride	Trace	....	....	....	....
Magnesium chloride	0.12	....	....	Trace	0.55
Sodium sulphide	....	....	....	Trace	....
Alumina	....	Trace	....	....	....
Silica	0.02	0.02	[f]0.03	[f]0.03	0.04
Bromine	Trace	....	....	....	....
Boracic acid	Trace	....	[g]Trace	Trace	....
Loss	0.01	....	....	....	....
Total	5.39	6.28	0.55	0.87	5.47

Constituents.	Rockcastle Chalybeate Spring.	Sowder's Spring.	Trice's Salt-Sulphur Well.	Mineral Well, Walnut Hill.	Williams's Mineral Well.
	Pts. in 1,000.[a]	*Grs. in* 1,000.[a]	*Pts. in* 1,000.[a]	*Grs. in* 1,000.[a]	*Grs. in* 1,000.[a]
Sodium carbonate	....	....	0.24	Trace	....
Calcium carbonate	0.0438	0.51	0.12	0.18	Trace
Magnesium carbonate	0.0148	0.38	0.03	0.04	Trace
Manganese carbonate	....	....	Trace	....	....
Iron carbonate	0.0145	Trace	Trace	Trace	....
Sodium sulphate	0.0531	0.40	0.53	....	....
Potassium sulphate	....	0.30	....	....	....
Calcium sulphate	0.0029	1.57	0.12	0.34	....
Magnesium sulphate	0.0036	2.99	0.43	....	....
Sodium chloride	0.0026	1.00	3.36	4.01	2.34
Calcium chloride	....	....	....	0.01	0.82
Potassium chloride	....	....	Trace	0.08	0.01
Magnesium chloride	....	....	....	0.32	0.28
Magnesium iodide	....	....	Trace	....	....
Sodium sulphide	....	....	([g])	....	....
Alumina	....	....	Trace	....	....
Silica	0.0128	....	0.01	0.02	[h]0.60
Iodine	....	....	....	Trace	....
Bromine	....	....	Trace	Trace	....
Boracic acid	....	....	Trace	....	....
Total	0.1481	7.15	4.84	4.95	3.55

[a] Robert Peter, analyst.
[b] Robert Peter, analyst (1877).
[c] Robert Peter, analyst (1880).
[d] Robert Peter, analyst (1861).
[e] With phosphates.
[f] With loss.
[g] Not estimated.
[h] With sulphuric acid, bromine, alumina, loss.

Analyses of mineral springs in Kentucky—Continued.

Constituents.	Mineral Well, Paint Lick.	Burgher's Spring, or Fountain of Life.	Clear Creek Sulphur Springs.	Davis Mineral Well.	Kuttawa Mineral Springs.	Wilson's Saline-Chalybeate Spring.
Solids.		*Parts in 1,000.*[a]	*Parts in 1,000.*[a]	*Grains per gallon.*[b]	*Parts in 1,000.*[c]	*Grains per gallon.*
Sodium carbonate	0.28		0.03			
Calcium carbonate	0.03	0.35	0.04		0.16	0.93
Magnesium carbonate	Trace	0.04	Trace			14.63
Iron carbonate	Trace					2.51
Alkaline carbonates					1.19	
Sodium sulphate	0.03			0.94	0.20	
Potassium sulphate	0.07			1.76		
Calcium sulphate	0.03	1.19	0.01	71.23		1.84
Magnesium sulphate	0.02	0.94	0.02	43.47	0.39	1.09
Aluminium sulphate		Trace		83.16		
Lithium sulphate		Trace				
Iron sulphate		Trace		9.21		
Sodium sulphate					0.42	
Calcium phosphate	Trace					
Sodium chloride	0.46	0.09		6.31	0.45	5.30
Calcium chloride			Trace			33.49
Potassium chloride						2.59
Magnesium chloride						17.66
Magnesium bromide						0.79
Alumina					1.20	
Silica	0.04	0.01	0.01	0.74		1.46
Silicates					0.05	
Organic matter				0.86		
Total	0.96	2.92	0.11	217.18	4.06	82.63
Gas.						*Cub. inches.*
Carbonic acid					3.09	33.84

[a] Robert Peter, analyst.

[b] E. S. Wayne, analyst (1882).

[c] J. P. Barnum, analyst.

ARKANSAS.

Among mineral spring States Arkansas occupies a prominent place. The reputation of her famous Hot Springs, which have been more or less improved and utilized for medicinal purposes since the early part of the century, has attracted attention to the subject throughout the State and has led the people to appreciate the value of their springs.

Although a large proportion of the springs have been improved, very few appear to have been subjected to quantitative chemical analysis. Only five are given in the table. The list of springs is based mainly upon data obtained from Owens's geological reports of Arkansas, supplemented, as in the case of most of the other lists, by information derived directly from persons interested in the various springs. Of the springs whose general character is known, probably half are chalybeate and nearly that number are also sulphureted.

Only about five are utilized commercially at present.

Mineral springs of Arkansas.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Alum Spring, 3 miles west of Camden, Ouachita County.					
Armstrong Spring, 5 miles west of Searcy, White County.					
Baker's Spring, section 14, township 5 south, range 30 west, Howard Co.	1		61	Saline, sulphureted.	Resort.
Black Sulphur Springs, Van Buren Co.					
Blanchard Springs, Blanchard Springs, Union County.	17	1,700		Saline, &c	Do.
Blanco Springs, 12 miles northwest of Hot Springs, Garland County.	3				
Blood Spring (Ryder's), Montgomery County, 50 miles west of Hot Springs.	1	2,000	65	Saline, chalybeate.	Do.
Blowing Springs, 6 miles southwest of Springfield, Conway County.				Sulphureted ?	Unimproved.
Bog Springs, near Paraclifta, Sevier Co.					Do.
Britt's Springs, Union County					
Bull Dog Mineral Springs, Montgomery County.					
Bussey's Mineral Spring, near El Dorado, Union County.				Saline, chalybeate.	
Butler's Mineral Spring, near Magnolia, Columbia County.			63	do	
Cantrell Springs, 9 miles from Pine Bluff, Jefferson County.					
Chalybeate springs:					
Near Benton, Saline County					Do.
Near Danville, Yell County			62	Saline, chalybeate.	
Near Benner's Mill, Franklin Co					Do.
Near Huntsville, Madison County				Saline, chalybeate.	
Near Malvern, Hot Spring County					
Near Rose Bud, White County	2	40	58	Chalybeate	Used locally.
At Peach Orchard Gap, White Co					
At Springfield, Conway County				Chalybeate and sulphureted.	
In Scott County					
In Van Buren County ?					
Near White Rock, Franklin County					Unimproved.
Five miles southeast of Harrisburg, Poinsett County.				Chalybeate	Do.
Chalybeate Hill Springs, Scott (?) Co				Saline, sulphureted.	
Cherokee Springs, Benton County					
Cluster Springs, 3 miles east of Hot Springs, Garland County.	15+			Chalybeate	Resort.
Crawford Sulphur Springs, near Sumpter, Bradley County.				Alkaline, sulphureted.	
Crystal Mineral Springs, near Crystal Springs, Montgomery County.			70	Chalybeate and saline.	
Dardanelle Sulphur Springs, 11 miles west of Dardanelle, Yell County.	4	110		Sulphureted, saline.	Local resort.
De Soto Mineral Springs, De Soto Springs, Searcy County.					
Dovepark Springs, Hot Spring County, near Dovepark.	12	2,160			Used commercially and as a resort.
Edmondson Springs, near Jordanbrook, Sevier County.					Unimproved.
Eldorado Springs, Benton County					
England's Mineral Well, near Harrisburg, Poinsett County.				Alkaline, sulphureted.	Do.
Excelsior Springs, near Yellville, Marion County.		25			Used locally.
Eureka Springs, Eureka Springs, Carroll County.	30	2,710	58 to 60	Calcic	Used commercially and as a resort.
Elm Store Springs, Elm Store, Randolph County.	3	360	62		
Fairchild's Potash Sulphur Springs, Potash Sulphur, Garland County.	42	1,675	58 to 70		Do.

Mineral springs of Arkansas — Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Flood's Chalybeate Spring, 10 miles north of Crystal Springs, Montgomery County.	......	9,000	....	....	
Gap Springs, Howard County..........	......	....	.....	Alkaline, sulphureted.	
Gillen's White Sulphur Spring, 8 miles east of Hot Springs, Garland Co.	1	....	.....	Saline ?	
Gray's Mineral Spring, section 20, township 5 north, range 29 west, Scott County.	......	....	.....	Alkaline, sulphureted.	
Green's Chalybeate Springs, near Buckville, Montgomery County.	......	....	.....	....	
Gum Springs, Gum Springs, Cleveland County.	1+	25	.....	Sulphureted	Local resort.
Hickory Creek Sulphur Spring, near Hickory Creek, Hempstead Co.	......	....	.....	do	Unimproved. ?
Hot Springs, Hot Springs, Garland Co.	71	20,100	93 to 157	Thermal........	Resort.
Hubbard's Mineral Spring, 3 miles north of Prairie D'Anne, Hempstead County (?).	.....	....	.....	Saline, chalybeate.	
Hutchinson's Sulphur Springs, Montgomery County, near Big Fork.	......	....	.....	....	
Iron Sulphur Spring, Iron Springs, Montgomery County.	......	....	.....	Alkaline, saline.	
Leay's Springs, 5 miles north of Warren, Bradley County.	......	....	.....	....	
Lee's Springs, 10 miles from Pine Bluff, Jefferson County.	5	175 to 300	43	....	Do.
Lemon's Chalybeate Springs, Montgomery County.	......	....	.....	....	
Mammoth Spring, Fulton County	1	....	57 to 60	Calcic	
Mattock's Spring, 8 miles west of Princeton, Dallas County.	1	....	.....	Sulphureted, saline.	
Maybury Springs, Montgomery County, 17 miles west of Hot Springs.	50+	....	64	Saline	Do.
Mineral springs:					
In section 16, township 12 south, range 10 west, Bradley County.	......	....	.....	....	
At Clear Spring, Clark County	......	....	.....	Sulphureted, chalybeate.	Used locally.
At Crystal Springs, Montgomery Co	......	....	70	Sulphureted and chalybeate.	
At Forrest City, St. Francis County	......	....	.....	....	
Five miles south of Harrisburg, Poinsett County.	......	....	.....	Chalybeate	Unimproved.
In and near Mineral Springs, Howard County.	4	560	60 to 64	Sulphureted, chalybeate, &c.	Resort.
At Mineral Springs, Howard Co ...	......	....	.....	....	
Thirteen miles from Van Buren, Crawford County.	......	....	.....	....	
In Sharp County	......	....	.....	....	Unimproved.
In section 9, township 5 north, range 18 west, Perry County.	......	....	.....	....	Do.
In section 25, township 10 south, range 25 west, Hempstead Co.	......	....	.....	Saline...........	
Mitchell's Chalybeate Springs, Stone Quarry Creek, Hot Spring County.	......	....	.....	Alkaline, saline.	
Mountain Valley Springs, 12 miles northwest of Hot Springs, Garland County.	3	64	.....	Calcic	Used commercially and as a resort.
Mount Nebo Springs, 5½ miles from Dardanelle, Yell County.	5	190+	50 to 54	Chalybeate	Resort.
National Springs, National, Logan Co.	......	....	.....	....	Do.
Newton Springs, section 26, township 3 north, range 12 west, Pulaski Co.	......	....	.....	Chalybeate	

Mineral springs of Arkansas — Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Pennywits Sulphur Springs, Crawford County.				Sulphureted	Resort.
Perryville Salt Well, Perryville, Perry County.				Saline	
Rabourn Sulphur Springs, Mount Ida, Montgomery County.					
Ravenden Springs, Ravenden Springs, Randolph County.				Alkaline	Do.
Rice's Spring on Mud Creek, Randolph County.			82	Carbonated, chalybeate.	Do.
Royston's Chalybeate Springs, section 33, township 7 south, range 25 west, Pike County.				Saline, chalybeate.	
Saratoga Springs, Saratoga, Howard County.					
Sawyer's Spring, 2½ miles east of Elm Springs, Washington County.					
Scoby's Springs, 5 or 6 miles north of Warren, Bradley County.					
Scott's White Sulphur Springs, near Black Springs, Montgomery County					
Searcy Springs, Searcy, White County.				Sulphureted, chalybeate, &c.	Do.
Shover's Spring, section 7, township 13 south, range 23 west, Hempstead Co.	1	120	63	Chalybeate	Do.
Siloam Springs, Siloam Springs, Benton County.	29	12,800	57 to 59		
State Salt Springs, section 30, township 11 north, range 28 west, Franklin County.					
Sugar Loaf Springs, Van Buren (?) Co.					
Sulphur and Chalybeate Springs, 1 mile from Hopeville, Calhoun Co.	5				Used commercially prior to the war.
Sulphur springs:					
Three miles from Clarendon, Monroe County.					
Near Enders, Faulkner County					Resort.
Near Fayetteville, Washington Co.					
Near Dr. Kuykendall's, (?) Washington County.	2			Saline, chalybeate, and sulphureted.	
South of Malvern, Hot Spring Co.					
At Sulphur Springs, Benton Co.					
Four miles east of Witherspoon, Hot Spring County.					
In section 35, township 4 north, range 17 west, Perry County.					Unimproved.
Thomas Mineral Spring, Beaver Bend Creek, Calhoun County.					
Turkey Chalybeate Springs, near Crystal Springs, Montgomery County.					
Van Patten's Spring, 2 miles south of Walnut Grove, Cross County.				Chalybeate	
Warm Springs (or Rice's Spring), Warm Springs, Randolph County.	60	500	60.2	Alkaline	Resort.
Whisenant Chalybeate Springs, Kate's Branch of Ouachita, Montgomery Co.				Alkaline, chalybeate.	
White Sulphur Springs, 8 miles southwest of Pine Bluff, Jefferson Co.	6	480	57	Sulphureted	Do.
Witherspoon Mineral Springs, near Witherspoon, Hot Spring County.				Saline	Unimproved.
Witt's Springs, Witt's Spring, Searcy County.	4		55 to 60		Do.
Wittsburg Mineral Spring, Wittsburg, Cross County.					Do.
Woolley Springs, Woolley, Union Co.					

Analyses of mineral springs in Arkansas.

Constituents.	Eureka Springs: Basin Spring.	Hot Springs.	Mountain Valley Springs.	Ravenden Springs.	Warm Springs.
	Grains per gallon [a]	*Grains per gallon.* [b]	*Grains per gallon.* [c]	*Grains per gallon.* [d]	*Grains per gallon.* [d]
Sodium bicarbonate	0.15				
Magnesium carbonate		0.13		4.48	1.54
Magnesium bicarbonate	0.47		3.17		
Calcium carbonate		3.97		4.61	6.51
Calcium bicarbonate	4.43		12.66		
Lithium carbonate				1.26	0.27
Iron carbonate					0.78
Iron bicarbonate			2.17		
Sodium sulphate	0.09	0.38			
Potassium sulphate	0.13	0.23			
Calcium sulphate		0.11	2.54	Trace	0.81
Aluminium sulphate				2.36	
Sodium chloride	0.19	0.01		2.18	1.57
Potassium chloride					1.42
Magnesium chloride				2.98	
Calcium chloride				1.24	
Calcium silicate		0.46			
Chlorine Iodine			0.88		
Iodine		Trace		Trace	Trace
Bromine		Trace			
Iron sesquioxide		0.10			
Iron Alumina	0.08				
Alumina		0.45			0.49
Silica	0.31	1.87	0.38	0.82	1.09
Organic matter Volatile matter					1.84
Organic matter		0.70		1.86	
Volatile matter					
Water		0.14			
Phosphoric acid			0.02		
Loss					1.79
Total	5.85	8.55	21.82	21.79	18.11
Gases.				*Cubic inches.*	*Cubic inches.*
Carbonic acid				2.14	161.50
Atmospheric air				1.33	21.10
Ammonia	0.21				
Total	0.21			3.47	182.60

[a] Potter and Riggs, analysts (1880).
[b] E. Hills Larkin, analyst (1859).
[c] Chauvenet and Blair, analysts.
[d] Wright and Merrill, analysts.

INDIAN TERRITORY.

The list of springs for Indian Territory is doubtless incomplete, as very considerable portions of the Territory are but little known, especially in the western and northwestern sections.

Although several places are mentioned on the list as resorts, they are as a rule unimproved and are used principally during the summer by persons who camp near them in order to use the waters for medicinal purposes.

Mineral springs of Indian Territory.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Court-House Spring. Cherokee Nation...	....	......	...	Sulphureted	
Harkin's Sulphur Springs, 20 miles east of Doaksville, Choctaw Nation.	3	300+	40	Sulphureted, saline.?	Resort.
Kia-li-a-gee Springs, 15 miles east of Wetum-ka, Creek Nation.	2	......	...	....	Has a reputation among the Indians.
Oil springs:					
On Oil Creek, South of Mill Creek, Chickasaw Nation.	....	......	...	....	
Eighteen miles northeast of Tahlequah, Cherokee Nation.	....	......	..	Sulphureted, chalybeate, &c.	Resort in summer.
Six miles north of Claremore Station, Cherokee Nation.	....	......	...	....	
Seco Springs, 3 miles from McAlister, Choctaw Nation.	3	......	...	Sulphureted and chalybeate.	
Sulphur springs:					
Fifty miles south of Erin Springs, Chickasaw Nation.	....	......	...	....	Used in summer.
At Tulsa, Creek Nation	....	......	...	....	
Seven miles from Claremore Station, Cherokee Nation.	....	......	...	....	

LOUISIANA.

Available data as to Louisiana mineral springs are meager and the list given here is presumably incomplete. It is mainly compiled from information contained in letters from various portions of the State.

No analyses are presented, but the springs are probably similar to those of Mississippi, as the geological formations of the two States are largely the same. Salt or brine springs prevail in certain portions of the State, being common in Natchitoches and Rapides.

None of the medicinal waters is used commercially and those springs utilized as resorts appear to be mainly of local importance.

Walton describes only the De Soto Springs and the White Sulphur Springs of Catahoula.

Mineral springs of Louisiana.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Abita Spring, near Covington, Saint Tammany Parish.	1	400	° 70	Chalybeate, &c.	Resort.
Belle Cheney Springs, Calcasieu Parish	....	......	....	....	
Castor Sulphur Springs, Castor Sulphur Springs, Catahoula Parish.	4	......	....	....	Local resort.
Claiborne Springs, Claiborne Cottage, near Covington, Saint Tammany Parish.	2	......	....	Chalybeate ...	Resort.
Denham's Springs, Hill's Springs, Livingston Parish	....	......	....	....do	
De Soto Mineral Springs, 3½ miles from Grand Cane, De Soto Parish.	3	60+	60	....	Local resort.
Horseshoe Springs, near Covington, Saint Tammany Parish.	....	......	....	....	
Labatt's Springs, near Covington, Saint Tammany Parish.	....	......	....	....	Resort.
Long's Springs, near Minden, Webster Parish	....	......	....	....	
Mineral Springs, 30 miles south of Castor Sulphur Springs, Catahoula Parish.	....	......	....	....	
Samaritan Springs, near Covington, Saint Tammany Parish.	...	......	....	....	
Sulphur springs:					
Near Covington, Saint Tammany Parish	5	......	....	Sulphureted, &c.	Unimproved.
In Calcasieu Parish	....	......	....	....	
Welch Springs, 1 mile from White Sulphur Springs, Catahoula Parish.	4	......	....	Chalybeate ...	
White Sulphur Springs, White Sulphur Springs, Catahoula Parish.	....	.....	....	Sulphureted and chalybeate.	Resort.

TEXAS.

Walton's Mineral Springs of the United States gives three localities for Texas and Pepper's list includes five. There are, however, about twenty localities that are places of resort and at least seven the waters of which are on sale. Besides there are a great many springs at present unimproved, but which have local reputations for the curative effects of their waters. Mineral springs exist in at least thirty counties of the State.

The list as given here is made up partly from various maps and handbooks of Texas, supplemented by data derived from correspondence with persons in the localities thus obtained. The majority of the springs are still unanalyzed, but sulphureted waters appear to be most numerous. The occurrence of free sulphuric acid in so many springs is notable. Lampasas Springs, Burdett's Sour Mineral Wells, the Sour Lake Springs, and Hynson's Iron Springs appear to be those most widely known.

Mineral springs of Texas.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Alum Springs, near Paige, Bastrop Co.	......	......	......	......	Unimproved and unimportant.
Barksdale Spring, 20 miles west of Junction City, Kimble County.	1	......	......	Chalybeate	Unimproved.
Bauguss Mineral Springs, near Viola, Cass County.	2	75	......	......	Local resort.
Bells Mineral Wells, Blossom Prairie, Lamar County.	4	......	......	Saline	Resort, and to some extent commercially.
Bernard Sulphur Springs, near Spanish Camp, Wharton County.	......	......	......	Sulphureted	Was once used locally.
Burdett's Sour Mineral Wells, 7 miles north of Luling, Caldwell County.	1+	......	......	Saline	Resort, and used commercially.
Cardwell Mineral Spring, 8 miles northwest of Luling, Caldwell County.	......	......	......	......	
Carrizo Springs, Carrizo Springs, Dimmit County.	100	5,000 to 7,000	69	Saline	Unimproved.
Cedar Springs, Cedar Mills, Grayson County.	5	......	......	Sulphureted and chalybeate.	Once used as a resort.
Chandler's Spring, Lampasas, Lampasas County.	......	......	......	......	
Chalybeate springs:					
In Leon County	......	......	......	......	
On Trinity River, Madison Co.	......	......	......	......	
At Sulphur Springs, Hopkins Co. ..	......	......	......	......	
In Morris County	......	......	......	......	
In Bowie County	......	......	......	......	
At Alford's Bluff, Trinity County ..	......	......	......	......	
In Bell County	......	......	......	......	
Four miles east of Winnsborough, Wood County.	1	200	50–60	Chalybeate	Resort.
Coleman Springs, 6 miles southeast of Annona, Red River County.	3	......	......	Chalybeate and sulphureted.	Used to some extent as a resort.
Crabtree's Sour Wells, Sulphur Springs, Hopkins County.	2	......	......	Acid, chalybeate.	Resort and water sold.
Dalby Springs, Dalby Springs, Bowie County.	2	1,600+	61–62	Chalybeate, &c .	Used commercially and as a resort.
Duffau's Sulphur Wells, Duffau Wells, Erath County.	7	......	40	......	Resort.
Fairview Springs, Limestone County .	......	......	......	......	
Gooch Mineral Springs, Lampasas, Lampasas County.	......	......	......	......	
Gunpowder Spring, 8 miles northeast of Gilmer, Upshur County.	......	......	......	......	Has local reputation.
Hancock Springs, near Lampasas, Lampasas County.	......	......	......	......	
Hanna Spring, near Lampasas, Lampasas County.	1	......	......	Saline	
Hot Springs, on Rio Grande, 25 miles south of Eagle Springs, Presidio Co.	2	......	160	......	
Hot Springs, on Rio Grande, 2 miles above Hot Springs, Presidio County.	......	......	100	......	
Hughes's Springs, Hughes Springs, Cass County.	3	......	68	Chalybeate	Used as a resort.
Hynson's Iron Mountain Springs, 6 miles west of Marshall, Harrison Co.	15	......	56	Chalybeate	Used commercially and as summer resort.
Kellum Sulphur Springs, 10 miles north of Anderson, Grimes County.	......	......	......	......	
Kendall County Mineral Spring, 3 miles west of Boerne, Kendall Co.	1	200	......	Saline, chalybeate, and sulphureted.	Resort.
Kessler Springs, 4 miles from Alleyton, Colorado County.	......	......	......	Chalybeate	
Leonoland Spring, on Leon River and Noland Creek, near Belton, Bell Co.	......	......	......	Chalybeate	
Martin Springs, Martin Spring, Grayson County.	1	400	60	Chalybeate	Unimproved.
Middleton Spring, near Paige, Bastrop County.	1	......	......	Sulphureted	Unimproved and unimportant.
Mineral springs:					
In Archer County	......	......	......	......	Unimproved.
In Angelina County	......	......	......	......	
In Brazos County	......	......	......	......	Do.

Mineral springs of Texas—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Mineral springs—Continued.			°		
Two miles southwest of Linden, Cass County.	......	....	......	....	
Near Rusk, Cherokee County	......	....	......	Chalybeate and sulphureted.	
In Concho County	......	....	......	....	
In Eastland County	......	....	......	....	
Two miles from Harwood, Gonzales County.	......	....	......	....	
Four miles from Waelder, Gonzales County.	......	....	......	Acid	
In Hardeman County	......	....	......	....	
In Harrison County	......	....	......	....	
At Reily Springs, Hopkins County	......	....	......	....	
In Knox County	......	....	......	....	
In Marion County	......	....	......	....	
In Milam County	......	....	......	....	
Near Mount Enterprise, Rusk Co	......	....	......	....	
In Smith County	......	....	......	....	
Southwest of Coffeeville, Upshur County.	....	....	......	....	
In Tyler County	......	....	......	....	
In Wilbarger County	......	....	......	....	
Seven miles southeast of Will's Point, Van Zandt County.	....	....	......	....	
In Wilson County	......	....	......	Chalybeate and sulphureted.	
Along Yegua River, Washington County.	......	....	....	Saline	
Mineral Wells, Mineral Wells, Palo Pinto County.	140	....	......	....	Used as resort and to some extent commercially.
Mineral wells:					
At Burns, Cooke County	......	....	......	....	Has local reputation.
At Austin, Travis County	......	....	......	....	
At Lawrence, Kaufman County	......	....	......	....	
Moseley's Mineral Well, Bristol, Ellis County.	1	....	50	Saline	Unimproved.
Pate Sour Well, Sulphur Springs, Hopkins County.	1	....	......	Acid, calcic, and chalybeate.	
Pecan Spring, Lange's Mill, near Cherry Spring, Gillespie County.	1	21,600	50	....	
Piedmont Sulphur Springs, 10 miles northeast of Navasota, Grimes Co.	....	....		....	
Porter's Springs, Porter's Springs, Houston County.	......	....	......	Chalybeate and sulphureted.	Do.
Red Springs or Jarrett Springs, near Boston, Bowie County.	....	....	.....	....	Resort.
Saratoga Springs (formerly New Sour Lake), Saratoga, Hardin County.	9	30+	......	Acid and saline.	Do.
Seven Springs, near Fort Davis, Presidio County.	......	....	60	....	
Sour Springs, near Luling, Caldwell County.	80	1,200+	......	Acid	Used commercially and as resort.
Sour Lake Mineral Springs, near Sour Lake, Hardin County.	13+	....	......	Acid	Do.
Sulphur Springs, Sulphur Springs, Hopkins County.	3	....	....	....	
Sulphur Springs, near Black Jack Springs, Fayette County.	3	....	......	....	Used as resort to a limited extent.
Sulphur springs:					
At Millican, Brazos County	8	....	......	....	Resort.
In Comal County	......	....	......	....	
On Plum Creek, 3½ miles east of Luling, Caldwell County	....	....	......	....	Unimproved, but used locally.
On Sandus Creek, De Witt Co	......	....	......	....	Local resort.
In El Paso County	......	....	......	....	
Thirty miles west of Big Spring, Howard County.	......	....	......	....	
Near Cherry Spring, Gillespie Co	......	....	......	....	
In Gonzales County	......	....	......	....	
In Grimes County	......	....	......	....	
At Jasper, Jasper County	2	....	......	....	
In Johnson County	......	....	......	....	Unimproved.

Mineral springs of Texas—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr	Character of the water.	Remarks.
Sulphur springs—Continued.			°		
At Oakville, Live Oak County	.....	.....	.....	.....	Unimproved.
In Pecos County	.....	.....	.....	.....	
In Polk County	.....	.....	.....	.....	
Fifteen miles north of Annona, Red River County.	.....	.....	.....	.....	
In Somervell County	.....	.....	.....	.....	
On Colorado River, south of San Saba, San Saba County.	1	.....	.....	.....	Local resort.
Near Trinity, Trinity County	.....	.....	.....	.....	
Twelve miles from Victoria, Victoria County.	1	.....	.....	.....	
Eighteen miles west of Huntsville, Walker County.	....	.....	.....	.....	Unimproved.
Sutherland Springs, Sutherland Springs, Wilson County.	25 to 30	.....	.....	.....	Resort.
Texas Sour Springs (same as Cardwell Mineral Spring).	.....	.....	.....	.....	
Thorp's Springs, Thorp's Spring, Hood County.	2	600	.....	Alkaline	Do.
Weaver Well, Sulphur Springs, Hopkins County.	.....	.....	.....	Acid, calcic, and chalybeate.	
Wilson's Mineral Well, Beaver Creek, 15 miles west of Huntsville, Walker County.	1	.....	.....	Chalybeate	Unimproved, but used locally.
White Sulphur Springs, White Sulphur Springs, Cass County.	2	.....	.....	.....	Used to slight extent as a resort.
Wootan Wells, Wootan Wells, 3 miles from Bremond, Robertson County.	4	.....	63	.....	Used commercially and as a resort.
Wyser's Spring, 12 miles north of Huntsville, Walker County.	1	75	.....	Sulphureted	Used locally.

Analyses of mineral springs in Texas.

Constituents.	Fairview Springs.	Kendall Co. Mineral Spring.	Mineral Wells, Palo Pinto Co	
			Palo Pinto Well.	Duke Bitter Well.
	Grains per gallon.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Calcium carbonate	.....	.....	2.08	.....
Magnesium carbonate	.....	.....	4.66	.....
Sodium sulphate	5.65	.....	150.05	10.98
Calcium sulphate	1.30	.....	6.55	7.58
Magnesium sulphate	9.82	.....	18.84	13.28
Aluminium sulphate	[d]5.40	.....	.....	.....
Iron sulphate	.....	.....	.....	0.13
Iron protosulphate	2.06	.....	.....	.....
Sodium chloride	1.76	0.84	23.98	0.95
Potassium chloride	.....	.....	1.28	.....
Calcium chloride	.....	.....	5.58	.....
Chlorine in chlorides	.....	0.51	.....	.....
Aluminium oxide	.....	0.09	1.54	.....
Iron oxide	.....		.....	.....
Magnesia	.....	6.44	.....	.....
Calcium	.....	45.83	.....	.....
Silica	.....	0.35	1.86	0.22
Sulphuric acid	.....	67.25	.....	.....
Volatile matter	.....	.....	9.81	0.10
Organic matter	.....	.....		
Loss	.....	17.07	.....	.....
Total	25.99	138.38	226.23	33.24

[a] C. F. Chandler, analyst (1884).
[b] A. Merrill, analyst.
[c] Leon Routt, analyst (1884).
[d] With alumina.

Analyses of mineral springs in Texas—Continued.

Constituents.	Pate Sour Well, at Sulphur Springs.	Sour Lake Mineral Springs.		Sour Springs, Caldwell County.
		Spring No. 7.	Spring No. 9.	
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Calcium sulphate	84.71			125.01
Magnesium sulphate	22.99	2.63	1.59	16.17
Potassium sulphate				100.08
Aluminium sulphate		45.52	31.28	
Ferrous sulphate		17.20	7.71	7.58
Iron sulphate	69.19			
Soluble silicates				12.18
Sodium chloride	5.02			42.74
Magnesium chloride				132.84
Lithium chloride				Trace
Silica	1.95			
Sulphuric acid	1.82	16.67	6.18	7.26
Volatile matter	3.80			
Organic matter				
Loss				5.12
Total	188.98	82.02	46.76	448.98

Constituents.	Weaver Well.	Wootan Wells.			
		Well No. 1.	Well No. 2.	Well No. 3.	Well No. 4.
	Grains per gallon.[d]	*Grains per gallon.*[e]	*Grains per gallon.*[f]	*Grains per gallon.*[f]	*Grains per gallon.*[f]
Calcium carbonate	4.28				
Sodium sulphate	1.34				
Calcium sulphate	45.68				
Magnesium sulphate	24.35				
Potassium sulphate	0.85				
Aluminium sulphate	23.24				
Iron sulphate	33.42				
Calcium phosphate	0.63				
Sodium chloride	1.36				
Chlorine in chlorides		24.34	33.13	35.46	36.36
Iron protoxide		1.92			
Iron sesquioxide		0.99	11.08		13.06
Iron oxide					
Manganese oxide		0.54	0.44	15.05	0.57
Aluminium oxide					
Aluminium sesquioxide		1.22	1.56		3.46
Soda			14.58		18.10
Magnesia		13.11	11.38	17.49	22.75
Calcium oxide		25.21	25.89	27.10	28.11
Silica	1.42	3.28	2.82		4.08
Sulphuric acid	1.21	[g]59.67	[g]67.23	[g]79.25	86.41
Nitrous acid	Trace				
Volatile matter	2.47	9.62		12.25	
Organic matter					
Total	140.25	139.90	168.11	186.60	212.90

[a] Wright and Merrill, analysts.

[b] F. W. Mallet, analyst (1885).

[c] H. H. Dinwiddie, analyst.

[d] Juan K. Wright, analyst (1882).

[e] C. F. Chandler, analyst.

[f] W. M. Mew, analyst.

[g] In sulphates.

NORTHERN CENTRAL STATES.

The broad areas of Carboniferous rocks with underlying Devonian and Silurian strata that are spread over so large a portion of the Northern Central States would lead us to look in this section for mineral springs similar to those found along the western side of the Appalachians in the Atlantic States and in the northern portion of the Southern Central Division. Here, as in those sections, chalybeate, saline, and sulphureted springs predominate. Calcic springs are more numerous than in the other sections, while thermal springs are inconspicuous, such waters as are referable to this class being derived almost entirely from artesian borings.

As we proceed toward the northern part of the section and reach the metamorphic areas, the springs become more like those of the New England States.

The waters used commercially are second in number only to those so used in the Northern Atlantic States. A fair proportion of the localities are resorts, and we may expect the number so used to increase when the newer parts of the Northwestern and Western States are more thickly populated. Every year adds to the number of improved springs in these portions of the Northern Central States. Nebraska, at present, is the only State in the section for which we are unable to give a supposably complete list of mineral springs.

Summary for Northern Central States.

States.	Number of spring localities.	Number of individual springs.	Number of springs analyzed.	Number of spring localities used as resorts.	Number used commercially.	Total number of analyses.
Ohio	80	106	15	15	7	15
Indiana	101	151	28	18	7	29
Illinois	52	91	14	6	5	14
Michigan	44	76	28	19	4	29
Wisconsin	75	146	51	15	15	58
Minnesota	27	39	7	2	1	7
Dakota	28	20	6	2	0	6
Iowa	33	68	14	7	4	14
Missouri	183	441	28	27	7	28
Nebraska	3	3	0	0	0	0
Kansas	81	120	24	11	5	24
Total	601	1,276	215	122	55	224

OHIO.

The list of Ohio mineral springs is based upon material derived from the State geological reports. The list thus obtained, supplemented by information obtained through correspondence, was submitted to the inspection of Prof. Edward Orton, of Columbus, Ohio. Speaking of the list, in a letter, he says, "It might be indefinitely extended or it might be considerably reduced." Referring to the belt of black Devonian shale that traverses the State from Lake Erie to the Ohio Valley, he says: "This formation as a rule yields but little water. The springs issuing from it, except at the very base, are weak, but they carry iron and sulphur almost everywhere. In Adams County, for example, if there is one mineral spring there are thousands. Four are credited on the list. One of these is a place of resort, but the others are identical in character with hundreds of others on all sides. They have come into recognition possibly through the superior intelligence or energy of their proprietors, who call attention to them in one way or another. What is true of Adams County is equally true of Scioto, Pike, Ross, and Pickaway, and to a less extent of the northern counties that hold the shale. The list in Delaware County might be increased to hundreds. The springs that issue from the base of the formation often have good volume, and these make a group by themselves (Mineral Springs, Adams County; Campbell's Spring, Pike County, &c.). Very much the same line of remark applies to the so-called chalybeate springs, derived from the drift formation. * * * There are considerable districts in which a bed of bog-ore underlies the drift beds, and all the wells and springs in these districts might be called chalybeate."

Professor Orton thinks also that if all the calcic waters were included the list might be almost indefinitely expanded. As already intimated, we have included only those springs mentioned in the geological reports or of which definite information was secured by letter.

A complete list would perhaps include the saline and brine springs of the State, but they have been considered in another place.[1] A small proportion of the springs are utilized as resorts and the waters of a very limited number are used commercially.

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[1] See Mineral Resources of the United States, Calendar Years 1883 and 1884, article Salt, p. 836. Washington, 1885.

Mineral springs of Ohio.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Adams County Mineral Springs, Mineral Springs, Adams County.	2	80	° 56	Chalybeate	Resort.
Annapolis Sulphur Spring, Crawford County.					
Artesian Sulphur Wells, Oak Harbor, Ottawa County.					
Bellbrook Magnetic Spring, Bellbrook, Greene County.	1			Calcic	Used commercially and as a resort.
Bitter Artesian Well, Bryan, Williams County.					
Bitter Well, Hancock County					
Bitter Well, New Winchester, Crawford County.					
Blue Rock Spring, East Cleveland, Cuyahoga County.	1	560?	60	Saline, sulphureted.	Resort.
Campbell's Spring, Pike County					
Carey's Spring, Crawford County					
Castalia Springs, Castalia, Erie County.				Calcic	
Cedar Springs, New Paris, Preble Co					
Chalybeate springs:					
Opposite Bucyrus, Crawford Co					
Near Darrtown, Butler County	3			Chalybeate, sulphureted.	Unimproved.
At New Comerstown, Tuscarawas Co					
Near Eaton, Preble County					
Chalybeate and Sulphur Springs, near West Charleston, Miami County.					
Chenowith's Black Sulphur Springs (formerly Mershon's), Locust Grove, Adams County.	2	a			Used to small extent as a resort.
Cincinnati Artesian Well (1,245 feet), Cincinnati Gas-Works, Hamilton Co.				Sulpho-saline	
Cincinnati Sulpho-Saline Spring (artesian well 240 feet), Cincinnati, Hamilton County.			62	do	Was used commercially and as a resort.
Copeland's Iron Spring, Locust Grove, Adams County.				Chalybeate	
Crawford Sulphur Spring, Crawford Co					
Cuyahoga Lithia and Magnesia Springs, 10 miles south of Cleveland, Cuyahoga County.				Alkaline	Used commercially.
Delaware White Sulphur Spring, campus of Wesleyan University, Delaware, Delaware County.	1				
Eaton Mineral Well, Eaton, Preble Co					
Electro-Magnetic Springs, near Woodstock, Champaign County.	4	1,100+	49½		Used commercially and as a resort.
Erkenbrecker's Salt Well (271 feet), Ludlow Grove, Hamilton County.				Saline	
Green Mineral Spring, Green Spring, Seneca County.	1	375,000	50		Do.
Howland Springs, east of Warren, Trumbull County.				Sulphureted	Resort.
Knisely's Springs, 8 miles northeast of Bucyrus, Crawford County.	11				Summer resort.
Len-a-pe Magnetic Springs, Delaware, Delaware County.	2	700	47	Alkaline, calcic.	Used commercially and as a resort.
Lewis Centre Sulphur Springs, Lewis Centre, Delaware County.					
Massie's Sulphur Spring, 5 miles south of Locust Grove, Adams County.					
Messinger's Sulphur Spring, 2½ miles northwest of Locust Grove, Adams County.	1	60			Has been a resort to some extent.
Mineral springs:					
Near Xenia, Greene County					
Near Charlestown, Portage Co					Small and unimportant.
At Wilberforce, Greene County					Do.
Southwest of Eaton, Preble County	8			Sulphureted, &c	
Near Cumberland, Guernsey Co					
Near Edinburg, Portage County					
Near Freedom, Portage County				Chalybeate	Used locally.

Mineral springs of Ohio—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Mineral springs—Continued.			°		
Near Hudson, Summit County					
Near Idaho, Pike County					
Near Lodi, Medina County					
At Milton Centre, Wood County					
Near Zanesville, Muskingum Co.					
Mineral Well, Norwalk, Huron Co				Saline	
Newark Magnetic Springs, Newark, Licking County.					
Ohio Magnetic Spring, Magnetic Springs, Union County.	1	750	52	Alkaline, calcic.	Used commercially and as a resort.
Smalley's Black Sulphur Spring, 6 miles east of Locust Grove, Adams Co.					
Stryker Mineral Well, Stryker, Williams County.	1		50	Saline	Resort.
Sulphur and Chalybeate Springs, Penn Township, Morrow (?) County.					
Sulphur springs:					
Near Hemlock, Perry County					Used locally to some extent.
Half mile north of Lynchburg, Highland County.					Is a local resort.
At Bluffton, Allen County					
At Harlem Springs, Carroll Co					Unimproved.
Near Defiance, Defiance Co					Do.
Near Delhi, Hamilton County					
Near Eaton, Preble County					
In Milton Township, Mahoning Co.					
On Olentangy River, Delaware Co.					
At New Philadelphia, Tuscarawas County.					
In Riley Township, Putnam Co					
In Scioto Township, Delaware Co					
At Sulphur Spring, Crawford Co.					
One mile east of Zoar, Tuscarawas County.					Do.
Near Sulphur Grove, Montgomery County.					
Sulphur wells:					
In Benton Township, Ottawa Co.					
At Bucyrus, Crawford County					
In Defiance County					
In Ottawa Township, Putnam Co.					
In Paulding County					
In Van Wert County					
Tawawa Springs, Wilberforce, Greene County.	2			Chalybeate	Resort.
White Sulphur Springs, Adams Co					
White Sulphur Springs, Bath Township, Allen County.					
White Sulphur Springs, White Sulphur, Delaware County.					
Wyandot Magnetic Well (Matthew Orian's Well), 5 miles north of Upper Sandusky, Wyandot County.	1	400		Sulphureted	Used commercially and as a resort.
Yellow Spring, Yellow Springs, Greene County.	1	6,600	52		Once a resort; unimproved now.
Yellow Springs, Clarke County					

Analyses of mineral springs in Ohio.

Constituents.	Cincinnati Artesian Well.	Cincinnati Sulpho-Saline Spring.	Cuyahoga Lithia and Magnesia Springs.		Erkenbrecker's Salt Well.
			Lithia Well.	Bitter Water.	
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Magnesium carbonate	8.14	9.18			14.06
Calcium carbonate	17.33	19.34	11.08	8.75	6.33
Ferrous carbonate			0.82	0.47	
Sodium sulphate			4.14	11.48	
Magnesium sulphate			116.54	172.07	
Calcium sulphate	27.27	29.20	120.39	50.16	6.07
Potassium sulphate		2.30	4.38	1.57	
Aluminium sulphate				515.51	
Sodium phosphate		1.34			
Sodium chloride	519.60	534.77	222.19	8.05	4,300.10
Magnesium chloride	18.14	17.27			542.04
Calcium chloride	22.26	22.19			786.61
Potassium chloride	3.27	3.95			
Lithium chloride			2.74	4.26	
Aluminium chloride			17.67		
Iron chloride					53.46
Sodium bromide					28.21
Magnesium bromide	0.26	0.39			
Magnesium iodide	0.19	0.30			
Iron oxide	0.87	0.43			
Silica	0.49	0.79	15.87	19.81	1.22
Loss		0.76			
Total	617.82	642.16	515.82	791.58	5,738.10
Gases.	*Cubic inches.*	*Cubic inches.*			
Sulphureted hydrogen	7.76	7.27			
Carbonic acid	10.32	12.63			
Total	18.08	19.90			

Constituents.	Electro-Magnetic Springs.	Green Mineral Spring.	Len-a-pe Magnetic Springs.		Stryker Mineral Well.
			Spring No. 1.	Spring No. 2.	
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[d]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[e]
Magnesium carbonate	11.41	22.39		12.11	
Magnesium bicarbonate			15.21		
Calcium carbonate	26.24			17.73	68.30
Calcium bicarbonate			27.42		
Iron carbonate	0.16	19.70			
Iron bicarbonate					9.93
Magnesium sulphate		36.14	0.93	2.31	
Calcium sulphate		105.41	6.20	5.12	
Potassium sulphate	2.91		1.34		185.34
Iron sulphate		6.53			
Sodium chloride	13.64		3.35	2.15	231.86
Magnesium chloride	2.12				118.96
Calcium chloride	4.22		0.63		
Potassium chloride		2.48			
Potassium bromide		16.76			
Iron oxide			0.54	0.41	
Alumina		0.98		Trace	
Silica	0.24	6.10	0.05		2.63
Potassa				Trace	
Organic matter	0.39		0.03	0.81	
Hydro-sulphuric acid					4.49
Total	61.33	216.49	55.70	40.64	621.51
Gas.		*Cubic inches.*			
Carbonic acid		96.48			

[a] E. S. Wayne, analyst.

[b] 1882.

[c] E. S. Wayne, analyst (1882).

[d] O. N. Stoddard, analyst.

[e] S. H. Douglass, analyst (1870).

Analyses of mineral springs in Ohio—Continued.

Constituents.	Yellow Spring, Greene Co.	Ohio Magnetic Spring.	Bellbrook Magnetic Spring.	Cedar Springs: Washington Spring.	Blue Rock Spring.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate				2.26	
Sodium bicarbonate					1.00
Magnesium carbonate			7.20	5.82	56.81
Magnesium bicarbonate		17.61			
Calcium carbonate	19.57		15.52	3.96	3.75
Calcium bicarbonate		19.20			
Potassium carbonate					6.75
Iron carbonate				1.32	
Iron bicarbonate		0.16			
Sodium sulphate		0.42	0.03	0.18	
Magnesium sulphate		2.80			
Calcium sulphate	1.35	3.27	1.20	1.24	
Potassium sulphate		0.22	1.07		
Sodium phosphate					5.25
Calcium phosphate				2.18	
Sodium chloride	0.15	0.79	0.85	0.98	210.25
Magnesium chloride	0.17				
Calcium chloride	1.54				
Potassium chloride					16.10
Lithium chloride					2.16
Sodium bromide					Trace
Sodium iodide					0.20
Iron oxide	0.39		0.25		
Alumina		0.12		0.22	
Silica		0.24	0.67		1.00
Organic matter		0.57			
Total	23.17	44.90	26.79	18.11	303.27

[a] Wayne and Locke, analysts.
[b] E. S. Wayne, analyst (1882).
[c] N. W. Lord, analyst (1883).
[d] A. Fennel, analyst.
[e] J. Lang Cassells.

INDIANA.

With the exception of Missouri, Indiana is credited in our list with more mineral-spring localities than any other of the Northern Central States. The geological formation being the same as in the neighboring States, we naturally find that the springs are also similar, and, as in Ohio, Illinois, and Kentucky, the sulphureted and chalybeate waters are most abundant. About the same number of localities are utilized for resorts as in Ohio and about as many of the waters are used commercially. We are able to present twice as many analyses as in the case of Ohio, but there are still some twenty-four springs the chemical characters of which are unknown. Brine springs exist in various portions of the State, but do not seem to be so numerous as in Ohio. The springs mentioned in the State geological reports of Prof. E. T. Cox form the basis of the list, and from the same source also many of the analyses have been taken.

Mineral springs of Indiana.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks.
Ague Chalybeate Springs, near Pikeville, Pike County.					
Albert's Sulphur Springs, between French Lick and West Baden, Orange County.	8				Unimproved.
Anderson Spring, on Fall Fork Creek, Bartholomew County.			53	Chalybeate	Has a local reputation.
Anderson Mound Springs, 3½ miles east of Anderson, Madison County.				do	Unimproved.
Artesian Well (900 feet), Rensselaer, Jasper County.	1	1,200	51	Sulphureted	Improved.
Avoca Mineral Spring, Avoca, Lawrence County.	1		50	do	Local resort.
Azalia Mineral Springs, 2 miles north of Azalia, Bartholomew County.			53	Chalybeate	Has local reputation.
Barlow's Thermal Well, Shelby Co				Sulphureted	
Benham's Carbureted Saline Well, near Mifflin, Crawford County.				Saline	
Blue Lick, Blue Lick, 1 mile east of Charlestown, Clark County.					Unimproved.
Boyer Sulphur Springs, Williamsport, Warren County.				Sulphureted	
Cameron Springs, Warren County, 4½ miles northwest of Attica.	2+	1,100+	50	Calcic, carbonated.	Resort; water to be sold in future.
Central Springs, 5 miles east of Shoals, Martin County.	5			Chalybeate	Resort.
Chalybeate springs:					
In sec. 8, T. 8, R. 10, near Graysville, Sullivan County.					
In sec. 21, T. 11, R. 6, Clay County					
In sec. 21, T. 11, R. 5, Clay County					
Nine miles northeast of Muncie, Delaware County.					
In Rochester, Fulton County					
Chalybeate and saline springs:					
In Putnam County					
In Floyd County					
In sec. 11, T. 21, R. 8, Warren Co					
Near Brownstown, Jackson County					
In Jeffersonville, Clark County					
Near Scottsburg, Scott County					
South of Williamsport, Warren County.				Saline, chalybeate.	
Near Sheridan, Hamilton County					
Near Cambridge City, Wayne Co					Unimproved.
Clark's Well, Crawford County					
Coats's Spring (same as West Saratoga Springs).					
Corydon Artesian Well, Corydon, Harrison County.				Saline, sulphureted.	
De Gonia Springs, De Gonia Springs, Warrick County.	2		55½	Saline, chalybeate.	Resort.
Eaton's White Sulphur Well, sec. 35, T. 3, R. 1 E., Crawford County.			59	Saline, sulphureted.	Do.
Fair Ground Springs, near Lawrence, Marion County.					
French Lick Springs, French Lick, Orange County.	13	1,100+	55	Saline, sulphureted.	Used commercially and as a resort.
Greencastle Springs, near Greencastle, Putnam County.	3+	480	51 to 56	Carbonated, alkaline, chalybeate.	Resort.
Hartford Sulphur Springs, Hartford, Ohio County.				Saline, sulphureted.	Do.
Hartsville Spring, Hartsville, Bartholomew County.			53	Chalybeate	Has a local reputation.
Hawkins's Chalybeate Springs, Richmond, Wayne County.				Sulphureted, chalybeate.	
Higgins Spring, near Orangeville, Orange County.					Unimproved.
Hosea Saline Sulphur or New Point Comfort Spring, Blue Lick, Clark County.	1	1½	43	Saline, sulphureted.	Used commercially and as a resort.

Mineral springs of Indiana—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Huffstetter's Chalybeate Springs, near Orleans, Orange County.					Has a local reputation.
Indian Springs, sec. 7, T. 4, R. 3, near Shoals, Martin County.		700+	56	Saline, sulphureted.	
Indian Springs, Trinity Springs, 9 miles north of Shoals, Martin Co.	6	120		Alkaline, calcic, and sulphureted.	Used commercially and as a resort.
Inlow Springs, 4 miles southeast of Muncie, Delaware County.	2			Chalybeate	Has a local reputation.
Kannal Spring, Rensselaer, Jasper County.	1	1,800	53	Sulphureted	Improved.
King's Mineral Springs, 1½ miles south of Wilson's Switch, near Blue Lick, Clark County.	8	150	48		Used commercially.
Knightstown Springs, 2 miles from Knightstown, Henry County.				Chalybeate	Once used as a resort, now occupied by Soldiers' Orphan Home.
La Fayette Artesian Well, La Fayette, Tippecanoe County.	1	480	58	Saline, sulphureted.	Used commercially.
Lambden's Mineral Springs, on Lost River, Orange County.					Unimproved.
Lodi Artesian Well, sec. 35, T. 18, R. 8, Fountain County.				Saline, sulphureted.	
Mayfield's Spring, Pleasantville, Sullivan County.					Do.
Marion Artesian Well, Marion, Grant County.			51½	Chalybeate	
Milburn Springs, near Winslow, Pike County.	8			do	Resort.
Minerva Mineral Spring, near Lawrence, Marion County.					
Mineral springs:					
At Centreville, Wayne County				Sulphureted	Local reputation.
Near Blue Lick, Clark County					
In Car Township, Clark County					
Near Henryville, Clark County				Saline	Unimproved.
At New Middletown, Harrison Co.				Saline, sulphureted.	Resort.
Near Muddy Fork, Monroe Township, Clark County.					
At New Providence, Clark County.					
Near Pleasantville, Sullivan County					
Near Rensselaer, Jasper County				Sulphureted	
Near Maywood, Marion County					
In section 17, Greene Township, Jay County.					
In section 85, Noble Township, Jay County.					
In Warren Co., near Cameron Spring					
Near Homer, Rush County					
Near Coesse, Whitley County					
On river bank, 1 mile from Rensselaer, Jasper County.		600 to 1,800	52	Sulphureted	
Four to 8 miles east of Rensselaer, Jasper County.		600 to 1,800	50	do	
Mineral Springs and Artesian Wells, near Rushville, Rush County.					Mostly unimportant and unimproved.
Mineral Artesian Wells, West Rushville, Rush County.				Chalybeate	
Mineral Well, New Mount Pleasant, Jay County.				Saline	
Ott's Well, Mifflin, Crawford County				do	
Peacock Spring, ½ mile from Rensselaer, Jasper County.	1	600 to 1,800	52	Sulphureted	
Rochester Chalybeate Spring, Rochester, Fulton County.					
Sand Creek Mineral Spring, near Azalia, Bartholomew County.	1	500	54	Chalybeate	Unimproved.

Mineral springs of Indiana—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Shelbyville Thermal Well, Shelbyville, Shelby County.	......	....	76	....	
St. Ronan's Well (30 feet), Boone Township, Warrick County.	1	30	50	Saline	Resort.
Sulphur springs:					
At Sulphur Springs, Henry County	......	80+	80	Sulphureted	Local reputation.
One and a half miles east of Henryville, Clark County.	......	....	....	....	Unimproved.
Near Maywood, Marion County...	......	....	....	....	
Near Rensselaer, Jasper County ..	......	....	....	....	
In Lawrence County	......	....	....	....	
On Flat Rock River, southern part of Shelby County.	......	....	....	....	
In section 17, Greene Township, Jay County.	......	....	....	....	
In section 35, Greene Township, Jay County.	......	....	....	....	
Sulphur Well, 8 miles south of Mifflin, Crawford County.	......	....	....	....	
Tar Springs, sec. 15, T. 3, R. 1 west, Crawford County.	......	....	....	Saline	Do.
Terre Haute Artesian Well, Terre Haute, Vigo County.	......	....	....	Saline, sulphureted.	
Thomas's Mineral Wells, Fountain Co.	......	....	...	Saline	
Trinity Springs, Trinity Springs, Martin County.	8	18,000	57	Saline, sulphureted.	Resort.
Van Cleave Mineral Springs, Crawfordsville, Montgomery County.	4	....	....	Chalybeate	Do.
Vickerman Springs, sec. 7, Nineveh Township, Johnson County.	8	....	....	....	
Vine's Springs, Vine's Springs, Ripley County.	7	400+	...	....	Do.
West Baden Springs, West Baden, Orange County.	5	1,500	57	Alkaline, saline, sulphureted.	Used commercially and as a resort.
West Saratoga Springs, West Saratoga Springs, Pike County.	......	....	...	Carbonated	Do.
White Sulphur Springs, Pike County..	......	....	....	....	
White Sulphur Springs, Bedford, Lawrence County.	......	....	....	....	
White Sulphur Springs, Indian Creek Township, Lawrence County.	......	....	....	....	
Wyandotte Spring, 5 miles northeast of Leavenworth, Crawford County.	......	....	..	Saline, sulphureted.	

Analyses of mineral springs in Indiana.

Constituents.	Anderson Mound Springs.	Benham's Carbureted Saline Well.	De Gonia Springs: Spring No. 1.	Eaton's White Sulphur Well.	Hartford Sulphur Springs.
Solids.	*Grains per imp. gallon.*[a]	*Grains per imp. gallon.*[b]	*Grains per gallon.*[c]	*Grains per imp. gallon.*[b]	*Grains per imp. gallon.*[b]
Magnesium bicarbonate		215.23		20.16	11.35
Calcium carbonate			16.00		
Calcium bicarbonate	10.90	795.91		57.02	24.69
Iron carbonate	1.18	10.71	4.00	2.88	2.26
Sodium sulphate		25.84	25.00	13.15	9.67
Potassium sulphate		28.06	7.00	6.48	1.57
Magnesium sulphate		104.54	56.00	52.77	14.76
Calcium sulphate	6.67	84.82	4.00	13.75	7.04
Calcium phosphate			2.00		
Sodium chloride		6,025.69		150.53	72.86
Calcium chloride			4.00		
Magnesium oxide	Trace				
Alkalies	Trace				
Silica			8.00		
Alumina	Trace				
Iodine	Trace				
Insoluble silicates	1.66				
Loss and undetermined	8.59				
Total	24.00	7,240.80	121.00	816.24	144.20
Gases.	*Cubic inches.*		*Grains per gallon.*		*Cubic inch.*
Carbonic acid	6.478		4.00		
Sulphureted hydrogen					0.785

Constituents.	French Lick Springs.			Greencastle Springs.	
	Proserpine Spring.	Pluto's Well.		North or Daggy Spring.	Middle or Dew Drop Spring.
Solids.	*Grains per wine gallon.*[d]	*Grains per imp. gallon.*[e]	*Grains per wine gallon.*[f]	*Grains per imp. gallon.*[g]	*Grains per imp. gallon.*[g]
Sodium carbonate	10.52	4.80		0.12	0.08
Magnesium carbonate	4.50	52.71	1.59	5.64	6.41
Calcium carbonate	20.29	40.18	6.95	17.47	14.27
Potassium carbonate		3.32		0.11	0.09
Iron carbonate	2.49		Trace	0.49	2.85
Aluminium carbonate					
Sodium sulphate	36.72	4.07	22.37	0.16	0.12
Potassium sulphate		1.21			
Magnesium sulphate	29.33	66.81	18.12	1 26	1.24
Calcium sulphate	141.00	15.61	60.59		
Aluminium sulphate		5.98			
Sodium chloride	90 92	141.90	140.54	0.95	0.84
Calcium chloride		32.90	5.85		
Potassium chloride	5.01				
Magnesium chloride	8.05	6.10			
Iodides		Trace			
Bromides		Trace			
Iron oxide		0.13			
Silica	1.69	0.66		0.10	0.01
Alumina			Trace	0.19	0.09
Loss				0.11	0.27
Undetermined matter			0.54		
Total	350.52	376.38	256.05	26.60	26.27
Gases.	*Cubic inches.*	*Cubic inches.*		*Cubic inches.*	*Cubic inches.*
Carbonic acid	10.116	7.337		3.62	3.58
Sulphureted hydrogen	17.000	6.717			
Oxygen		5.407			
Nitrogen		18.684			

[a] E. T. Cox, analyst (1878).
[b] G. M. Levette, analyst.
[c] 1876.
[d] J. G. Rogers, analyst (1869).
[e] E. T. Cox, analyst (1874).
[f] J. G. Rogers, analyst.
[g] E. T. Cox, analyst (1870).

Analyses of mineral springs in Indiana—Continued.

Constituents.	Hawkins's Chalybeate Springs.	Indian Springs.	Lodi Artesian Well.	La Fayette Artesian Well.	Marion Artesian Well.
	Grains per imp. gallon.[a]	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per imp. gallon.*
Sodium carbonate		4.38			
Magnesium carbonate		22.74	0.66	0.40	2.81
Calcium carbonate		89.78	2.01	12.02	16.80
Calcium bicarbonate	11.34				
Potassium carbonate	1.40	2.89			0.04
Ferrous carbonate	0.23				
Sodium sulphate		14.20	2.18		
Potassium sulphate		2.88	0.80		
Magnesium sulphate	1.92	86.48	3.26		4.06
Calcium sulphate	14.03		55.56	56.01	
Aluminium sulphate		0.99			
Iron sulphate		24.28			1.79
Calcium phosphate			1.20	[d]0.50	
Sodium chloride	0.40	47.26	502.46	324.77	0.39
Calcium chloride	0.39		47.93	3.72	
Magnesium chloride		.07	53.54	21.66	
Iodides		Trace			
Bromides		Trace			
Magnesium bromide			0.88		
Iron oxide		0.01			
Silica		0.54	0.52	0.46	1.61
Alumina					0.35
Manganese				Trace	
Iodine				Trace	
Sulphur			0.50		
Carbonic anhydride (dioxide)	2.44				
Organic matter				Trace	
Nitrogenous organic matter			0.80		
Silicates	0.19				
Total	32.34	196.45	672.45	419.54	27.85
Gases.					
	Cubic inches.	*Cubic inches.*			
Carbonic acid	5.1643	11.500		122.02	
Sulphureted hydrogen		4.000		22.96	
Oxygen		4.753			
Nitrogen		7.747		54.88	

Constituents.	Ott's Well.	Tar Springs.	Hosea Saline Sulphur Spring.	Trinity Springs.
Solids.	*Grains per imp. gallon.*[e]	*Grains per imp. gallon.*[a]	*Grains per imp. gallon.*[a]	*Grains per imp. gallon.*[f]
Sodium carbonate				0.14
Magnesium carbonate				4.93
Magnesium bicarbonate	107.04	2.49		
Calcium carbonate			88.20	6.71
Calcium bicarbonate	401.09	25.93		
Potassium carbonate				0.08
Iron carbonate	14.66	4.51		
Sodium sulphate	29.00	4.24	393.76	0.42
Potassium sulphate	11.10	2.03	111.25	0.11
Magnesium sulphate	42.75	10.80	11.33	5.00
Calcium sulphate	26.85		221.42	1.52
Aluminium sulphate			11.67	
Sodium chloride	4696.76		50.66	10.01
Calcium chloride				0.85
Magnesium chloride				1.82
Iodides				Traces
Bromides				
Ferric oxide				Trace
Silica				0.99
Total	5328.75	50.00	897.29	32.08
Gas.				
Sulphureted hydrogen	3.2			

[a] E. T. Cox, analyst.
[b] J. C. Pohle, analyst.
[c] C. M. Wetherell, analyst.
[d] With calcium fluoride, iron peroxide, and alumina.
[e] G. M. Levette, analyst.
[f] John F. Elsom, analyst (1883).

Analyses of mineral springs in Indiana—Continued.

Constituents.	West Saratoga Springs.		Terre Haute Artesian Well.	Thomas's Mineral Well.	Van Cleave Mineral Springs.
	Spring No. 1.	Spring No. 2.			
Solids.	*Grains per imp. gallon.*[a]	*Grains per imp. gallon.*[a]	*Grains per gallon.*[b]	*Parts in* 1,000.	*Grains per gallon.*[c]
Sodium carbonate					0.17
Sodium bicarbonate			0.52		
Magnesium carbonate					3.32
Magnesium bicarbonate			6.42		
Calcium carbonate				1.84	9.80
Calcium bicarbonate			25.03		
Potassium carbonate					0.14
Iron carbonate					0.62
Sodium sulphate					0.20
Magnesium sulphate					7.82
Calcium sulphate			2.82	0.05	
Calcium phosphate			Trace		
Calcium sulphide			Trace		
Sodium chloride			316.00	78.30	0.70
Calcium chloride			4.32	3.68	
Potassium chloride			1.23		
Magnesium chloride			6.43	0.91	
Alkaline chlorides		3.92			
Magnesium bromide			Trace		
Calcium oxide	2.43	3.94			
Alkalies	0.17				
Ferric oxide	2.25	2.07			
Iron oxide				0.03	
Silica			1.20		0.07
Alumina	0.22	0.43			
Chlorine	1.26	2.98			
Sulphuric acid	8.75	3.85			
Phosphoric acid	0.64	1.26			
Nitrogenous organic matter			1.10		
Insoluble matter	0.56	1.04			
Total	16.28	19.49	365.07	84.81	22.84
Gases.					
Carbonic acid			Present	0.02	
Sulphureted hydrogen			Present		

[a] E. T. Cox, analyst (1875). [b] J. G. Pohle, analyst. [c] T. M. Stevens, analyst.

Analyses of mineral springs in Indiana—Continued.

Constituents.	West Baden Springs.		Wyandotte Spring.	Cameron Springs.	St. Ronan's Well.
	Spring No. 1.	Spring No. 5.			
	Grains per imp. gallon.[a]	*Grains per imp. gallon.*[a]	*Grains per imp. gallon.*[a]	*Parts in* 100,000.[b]	*Grains in* 1,000 *cu. cm.*[c]
Sodium carbonate	1.34	11.64			
Magnesium carbonate	47.00	7.26			
Calcium carbonate	49.66	22.35	3.89		
Calcium bicarbonate				30.253	
Potassium carbonate	0.75				
Iron carbonate		3.60	0.28		
Aluminium carbonate					
Sodium sulphate	3.78	38.13	2.21		
Potassium sulphate	1.64		1.04		
Magnesium sulphate	42.89	33.33	29.49		
Calcium sulphate	13.42	130.07	6.45	3.178	
Aluminium sulphate	5.41				
Sodium chloride	96.60	97.46	0.58	0.568	
Calcium chloride	8.73				
Potassium chloride		7.36			
Magnesium chloride	13.69	11.04			
Iodides	Trace				
Bromides	Trace				
Magnesium oxide				10.301	20.70
Calcium oxide					9.80
Iron oxide	0.10				Trace
Silica	0.53		0.20	1.653	
Alumina					Trace
Sodium					0.40
Chlorine					0.62
Sulphuric acid					65.20
Carbonic anhydride (dioxide)			5.69		Trace
Organic matter					Trace
Loss			5.52		
Total	282.99	362.24	55.30	46.048	96.72
Gases.	*Cubic inches.*	*Cubic inches.*		*Cubic inches.*	
Carbonic acid	7.447	11.116		6.58	
Sulphureted hydrogen	6.821	2.505			
Oxygen	6.027	6.347		1.05	
Nitrogen	20.271	19.174		4.46	

[a] E. T. Cox, analyst. [b] Stockder, analyst (1884). [c] F. W. Achilles, analyst (1877).

ILLINOIS.

The State of Illinois appears to have a fair proportion of mineral springs, although so far as known very few are utilized either commercially or as resorts. Chalybeate, sulphureted, and saline waters predominate. Brine springs are found in a number of counties.

The most prominent source drawn upon in the preparation of the list given here has been the Economical Geology of Illinois, by A. H. Worthen, published in 1882, which republishes from the original six volumes on the geology of the State all that relates to its economical geology. Comparatively few of the Illinois mineral waters have been chemically analyzed.

Mineral springs of Illinois.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alcyone Mineral Springs, Western Springs, Cook County.	4	2,400	° 50		Used commercially.
Artesian Well, Illinois City, Rock Island County.					Resort.
Carbureted Spring, 4 miles northwest of Decatur, Macon County.				Carbureted and sulphureted.	
Chalybeate springs:					
In Boone County					
On Cache River, near Ullin, Pulaski County.					
On Cedar Creek, near Reynoldsburg, Johnson County.					
Near Fairfield, Wayne County					
Near McLeansborough, Hamilton County.					
Near mouth of Saline River, Hardin County.					
In sec. 2, T. 6 N., R. 5 E., Effingham County.					
In sec. 29, T. 11, R. 9, Hardin Co					
In sec. 12, T. 12, R. 4, Johnson Co					Was formerly a resort.
In sec. 29, T. 19, R. 5 E., Platt Co					
In sec. 25, T. 11, R. 6, Pope County					
Chalybeate Well, between Big and Talfer Creeks, Effingham County.					
De Foe's Mineral Well, McLeansborough, Hamilton County.				Chalybeate	
Dixon Springs, sec. 16, T. 13, R. 5, Pope County.				do	Resort.
Ganymede Spring, near Oregon, Ogle County.	1	3,000		Alkaline	Water is to be placed on sale.
Green Lawn Springs, Mount Vernon, Jefferson County.	7		52 to 62	Saline, chalybeate.	Resort.
Glen Flora Springs, near Waukegan, Lake County.	2	250	45	Alkaline	Used commercially and as a resort.
Holderman's Artesian Well, sec. 3, T. 33 N., R. 8 E., Grundy County.				Sulphureted	
House's Mineral Spring, sec. 15, T. 35, R. 8, Kendall County.				do	
McDaniel's Mineral Springs, north of McLeansborough, Hamilton County.				Saline, sulphureted.	Unimproved.
Mineral springs:					
In sec. 27, T. 9, R. 8, Gallatin Co				do	
In sec. 16, T. 11 S., R. 2 W., Calhoun County.				do	
At Jugtown, Grundy County					
On Mazon Creek, Grundy County				Sulphureted	

Mineral springs of Illinois—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Mineral springs—Continued.			°		
In sec. 6, T. 32 N., R. 8 E., Grundy County.	......	....	...	Sulphureted	
In sec. 23, T. 35, R. 8, Kendall Co ...	......	....	...	....	
In sec. 16, T. 35, R. 8, Kendall Co ...	......	....	...	Sulphureted	
Opposite Buffalo Rock, La Salle Co.	......	....	...	Saline	
At Lowell, La Salle County	......	....	...	Saline, sulphureted.	
On Clark's Run, near Utica, La Salle County.	......	....	...	Saline, sulphureted.	
At Warsaw, Hancock County	......	....	...	Saline, chalybeate.	
In sec. 22, T. 11 S., R. 2 W., Union County.	......	....	...	Carbureted	
In Washington County	......	....	...	....	
At Erie, Whiteside County........	......	....	...	....	
In sec. 27, T. 2 N., R. 6 E., Wayne County.	......	....	...	Saline	
Perry Springs, Perry Springs, near Perry, Pike County.	3	....	48 to 50	Saline, sulphureted, and chalybeate.	Used commercially and as a resort.
Phifer's Chalybeate Springs, sec. 31, T. 6 N., R. 2 E., Fayette County.	......	....	...	Chalybeate	
Rinnah Wells Springs, near Andalusia, Rock Island County.	3	....	...	Carbonated	Used locally.
Rockford Artesian Wells, Rockford, Winnebago County.	3	....	...	....	
Ross Mineral Springs, Prospect Hill, Saline County.	......	....	...	Saline, sulphureted.	
Sailor's Springs, Sailor Springs, Clay County.	......	....	...	....	
Schuyler County Spring, Schuyler County.	......	....	...	Saline, chalybeate.	
Spring Valley Springs, 3 miles east of Utica and 7 miles west of Ottawa, La Salle County.	20	2,000+	52	Saline, sulphureted.	Not improved as resort.
Sulphur Powder Spring, near Buck Horn, Brown County.	1	....	...	....	Unimproved.
Versailles Mineral Springs, near Versailles, Brown County.	4	....	...	Alkaline.........	Once a resort.
Voris & Co.'s Artesian Well, Tasewell County, opposite Peoria.	......	....	...	Saline, sulphureted.	
Wasson's Chalybeate Spring, sec. 25, T. 11, R. 6, Pope County.	......	....	...	....	
Western Saratoga Springs (hygienic springs), Western Saratoga, Union Co.	2+	1,000+	...	Carbonated	Resort.
Zonian Spring, near Elgin, Kane Co ...	......	....	46	....	Used commercially.

Analyses of mineral springs in Illinois.

Constituents.	Alcyone Mineral Springs.	Ganymede Spring.	Glen Flora Springs.	Perry Springs.		
				No. 1. Middle Iron Spring.	No. 2. Upper Magnesia Spring.	No. 3. Lower Sulphur Spring.
	Grains per imp. gall.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[d]	*Grains per gallon.*[d]
Sodium bicarbonate			6.45			
Potassium carbonate		0.908		1.59	1.45	1.46
Calcium carbonate		9.200				
Calcium bicarbonate	18.69		15.57	15.89	19.75	19.66
Magnesium carbonate		8.595				
Magnesium bicarbonate.	13.79		11.09	17.01	14.81	10.49
Iron bicarbonate			0.11	0.55	0.40	0.27
Sodium sulphate	3.39		1.85	0.44	1.10	1.49
Potassium sulphate	4.86	0.156				
Sodium chloride		0.101	0.18			
Potassium chloride		0.026				
Aluminium silicate						0.27
Potassium silicate				[e]2.64	[e]2.28	[e]3.45
Sodium silicate				0.12	0.38	0.58
Silica	0.68	0.962	0.91			
Oxide, iron and alumina		0.061				
Organic matter			0.10			
Alumina	[f]1.99		0.15			
Carbonic acid (free)	4.68					
Sulphur			Trace			
Total	48.08	20.024	36.41	38.24	40.17	37.67

Constituents.	Schuyler County Spring.	Versailles Mineral Springs.			Spring Valley Springs.		Rockford Artesian Well, No. 1.	Zonian Spring.
		No. 1.	No. 2.	Magnetic Spring.	No. 1.	No. 2.		
Solids.	*Grains per gall.*[c]	*Grains per imp. gall.*[a]	*Grains per imp. gall.*[c]	*Grains per gall.*[g]	*Grains per gall.*[h]	*Grains per gall.*[h]	*Parts in 1,000.*[i]	*Grains per gall.*[j]
Sodium bicarbonate		10.99	10.99					
Sodium carbonate				1.32				0.457
Potassium carbonate								
Potassium bicarbonate		Trace	Trace					
Calcium carbonate				14.60	8.96	7.28	.1396	9.568
Calcium bicarbonate		17.43	23.22					
Magnesium carbonate				8.95	3.40	4.00	.1258	2.496
Magnesium bicarbonate.		12.57	11.78					
Ferrous carbonate				0.06				
Iron carbonate								0.499
Iron bicarbonate			[k]2.14					
Sodium sulphate					35.16	14.56	.0095	1.747
Potassium sulphate							.0090	
Calcium sulphate	73.94	2.08		Trace	3.84	1.60		
Alkaline sulphate	7.84							
Magnesium sulphate	2.98				9.12	4.32		
Iron protosulphate	69.96							
Sodium phosphate							Trace	
Sodium chloride		Trace	Trace	Trace	34.80	25.28	.0062	0.707
Calcium chloride					38.72	18.16		
Magnesium chloride								
Silica	1.31	0.82	1.70	1.40			.0107	0.266
Alumina		[l]0.73					.0009	
Organic matter		Trace	Trace		0.24	0.27		
Ferric oxide							.0006	
Total	156.03	44.62	49.83	26.33	129.24	75.47	.3028	15.740
Gas.	*Cubic in.*	*Cubic in.*	*Cubic in.*	*Cubic in.*	*Cubic in.*	*Cubic in.*	*Cubic in.*	
Carbonic acid				24.00				6.828

[a] Wheeler & Blaney, analysts.
[b] E. M. Hall, analyst (1885).
[c] J. V. Z. Blaney, analyst.
[d] Henry Engleman, analyst.
[e] With soda.
[f] With iron.
[g] G. A. Mariner, analyst.
[h] James R. Chilton, analyst (1853).
[i] Erastus G. Smith, analyst.
[j] J. E. Siebel, analyst.
[k] With trace of alumina.
[l] With trace of iron.

MICHIGAN.

The mineral waters of Michigan are derived to a great extent from wells, which are nevertheless locally termed mineral springs. Many of these wells are artesian and were frequently sunk originally for other purposes than to find mineral waters. The artesian borings are especially in the corniferous limestone and the Huron group (Devonian). Prof. Alexander Winchell says: "The conformation of the strata has retained all their original soluble constituents; hence all artesian waters in the State, save some outlying leached-out patches of the Parma sandstone, will be found mineralized." The waters are classed as saline, carbonated, and sulphureted. The saline and sulphureted springs predominate. The brines of Michigan (which are not included in our list) form an important factor in the industries of the State, nearly half of the salt product of the United States being credited to Michigan. The supply is derived mainly from artesian borings. So-called magnetic springs are prominent. Professor Winchell says their waters are not themselves magnetic, but that marked magnetic phenomena manifest themselves about the wells.

The list, as given here, has been drawn principally from State geological reports and from an essay on the magnetic and mineral springs of the State, by Dr. Stiles Kennedy.

Mineral springs of Michigan.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alpena Magnetic Well, Alpena, Alpena County.	......	.....	° 52	Sulphureted	Resort.
Berrien Springs, Berrien Springs, Berrien County.	......	......	......	....	
Butterworth's Magnetic Spring, Grand Rapids, Kent County.	1	......	......	Saline	Do.
Cascade Springs	......	.....	.....	....	
Chalybeate springs:					
Near Ann Arbor, Washtenaw Co...	......	......	......	....	
At Canton, Wayne County	......	......	......	....	
At Ecorse, Wayne County	......	......	......	....	
At Flat Rock, Wayne County......	......	......	......	....	
At Van Buren, Wayne County....	......	......	......	....	
Near Springville, Lenawee County.	......	......	......	....	Unimproved.
Eaton Rapids Magnetic Springs and Well, Eaton Rapids, Eaton County.	11	.....	......	Calcic	Resort.
Erie Sulphur Springs, Erie, Monroe Co	2	......	......	....	Has local reputation.
Flint's Magnetic Springs, Three Rivers, Saint Joseph County.	......	......	......	Saline	
Fruitport Artesian and Magnetic Well, Fruitport, Muskegon Co.	......	......	48	Saline, sulphureted.	Resort.
Grand Haven Mineral Spring, Grand Haven, Ottawa County.	....	......	......	Saline	Do.
Grand Ledge Magnetic Wells, Grand Ledge, Eaton County.	2	......	......	Calcic	Do.
Hubbardston Magnetic Spring, Hubbardston, Ionia County.	......	.....	......	Calcic, chalybeate.	Do.
Lansing Magnetic Well (1,400 feet) or Michigan Congress Spring, Lansing, Ingham County.	1	60?	53.5	Saline	Do.

Mineral springs of Michigan—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Leslie Magnetic Wells, Leslie, Ingham County.	3	....	......	Calcic, carbonated.	Resort.
Midland Magnetic Well, Midland, Midland Co.	......	......	47	Saline	Do.
Mineral Well, Arcade building, Grand Rapids, Kent County.	..	......	......	Calcic	
Moorman Well, Ypsilanti, Washtenaw County.	1	......	57½	Saline, sulphureted.	Used commercially and as a resort.
Mount Clemens Mineral Springs, Mount Clemens, Macomb County	2	....	....	Saline	Used commercially.
Ogemaw Mineral Springs, Ogemaw Springs, Ogemaw County.	8	......	......	Chalybeate, &c	Local reputation.
Otsego Mineral Springs, Otsego, Allegan County.	10	......	....	....	Resort.
Owosso Chalybeate Spring, Owosso, Shiawassee County.	1	....	......	Chalybeate	Do.
Owen's Mineral Well, Ypsilanti, Washtenaw County.	1	......	56.6	Saline, sulphureted.	Used commercially.
Riverside Magnetic Mineral Springs, Springwell's Fort, near Detroit, Wayne County.	2	......	50	Calcic, saline....	Bathing resort.
Saint Clair Mineral Spring, Saint Clair Springs, Saint Clair County.	....	.....	.....	Saline ...	
Saint Louis Magnetic Spring, Saint Louis, Gratiot County.	.....	......	50	Alkaline, carbonated.	Do.
Spring Lake Magnetic Well, Spring Lake, Ottawa County.	....	......	52	Saline	Resort.
Shawnee Mineral Springs, Monroe, Monroe County.	......	....	47 to 49	Alkaline, calcic.	Sanitary resort.
Sulphur springs:					
In Ash Township, Monroe County	......	......	......	....	
In Brownstown Township, Wayne County.	......	......	......	....	
In Exeter Township, Monroe Co...	......	......	......	....	
At Dearborn, Wayne County	......	......	......	....	
Near Dundee, Wayne County	......	......	......	....	
At Gibraltar, Wayne County	....	......	......	....	
Near La Salle, Monroe County.....	......	......	......	....	
Near Monroe, Monroe County ...	......	......	......	....	
Near Raisinville, Monroe County ..	......	......	......	....	
Warner's Spring, Albion, Calhoun Co..	...	......	......	Weak alkaline, calcic.	
Wyandotte White Sulphur Spring, 10 miles from Detroit, Wayne County.	......	......	......	Sulphureted	Bathing resort.
Ypsilanti Mineral Well, Ypsilanti, Washtenaw County.	1	......	58.1	Saline, sulphureted.	Used commercially and as a resort.

Analyses of mineral springs in Michigan.

Constituents.	Eaton Rapids Magnetic Springs and Well.				
	Bodine Spring.	Frost Well.	Mosher Spring.	Shaw Spring.	Sterling Spring.
Solids.	*Grains per gallon.*[a]	*Grains per imp. gallon.*[b]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[e]
Sodium carbonate	....	....	5.38	11.57	....
Sodium bicarbonate	5.05	....	....	....	....
Potassium carbonate	....	....	1.15	1.27	....
Potassium bicarbonate	3.00	....	....	....	....
Calcium carbonate	....	46.24	19.43	20.74	....
Calcium bicarbonate	40.47	....	....	....	....
Magnesium carbonate	....	9.11	4.52	3.84	....
Magnesium bicarbonate	8.40	....	....	....	....
Iron carbonate	....	2.36	....	....	2.80
Iron bicarbonate	2.25	....	1.00	2.23	....
Sodium sulphate	....	....	....	....	12.59
Calcium sulphate	57.50	4.64	45.16	48.13	55.20
Magnesium sulphate	....	....	....	....	9.40
Sodium chloride	1.50	9.21	0.90	0.90	[d]5.21
Silica	2.00	15.74	2.54	1.40	....
Organic matter	....	0.90	0.85	0.90	....
Loss	....				....
Total	120.17	88.22	80.93	90.98	85.20
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	
Carbonic acid	17.35	22.22	15.38	15.97	....

Constituents.	Fruitport Artesian and Magnetic Well.	Alpena Magnetic Well.	Butterworth's Magnetic Spring.	Riverside Magnetic Springs.	
				Spring No. 1.	Spring No. 2.
Solids.	*Grains per gallon.*[c]	*Grains per gallon.*[b]	*Grains per imp. gallon.*[b]	*Grains per gallon.*	*Grains per gallon.*
Sodium carbonate	....	....	....	....	2.80
Sodium bicarbonate	6.52	15.74	6.00	....	....
Calcium carbonate	....	....	....	16.40	11.15
Calcium bicarbonate	5.11	55.14	10.01	....	0.22
Magnesium bicarbonate	4.15	62.92	7.02	....	....
Iron carbonate	....	....	....	....	0.10
Iron bicarbonate	7.50	1.84	1.17	....	....
Manganese bicarbonate	0.10	....	....	....	....
Sodium sulphate	46.00	....	....	....	....
Calcium sulphate	....	80.06	90.19	114.42	160.77
Magnesium sulphate	....	....	....	44.32	....
Sodium chloride	464.03	68.25	15.28	31.79	310.55
Potassium chloride	0.43	....	11.79	....	....
Calcium chloride	111.11	....	7.33	....	42.58
Magnesium chloride	46.81	....	50.24	25.96	109.77
Bromide	0.77	....	....	....	....
Alumina	Trace	3.09	0.49	....	[f]0.51
Silica	10.60		0.62	Trace	0.21
Organic matter	....	0.92	0.80	....	....
Loss	....			....	....
Total	703.13	237.96	200.94	232.89	638.66
Gases.	*Cubic inches.*	*Cubic inches.*		*Cubic inches.*	*Cubic inches.*
Carbonic acid	7.00	8.40	....	....	....
Sulphureted hydrogen	....	35.36	....	19.02	14.77
Nitrogen	....	0.24	....	....	....

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[a] R. C. Kedzie, analyst.
[b] S. P. Duffield, analyst.
[c] C. T. Jackson, analyst.
[d] With sodium carbonate.
[e] C. G. Wheeler, analyst.
[f] With calcium phosphates.

Analyses of mineral springs in Michigan—Continued.

Constituents.	Grand Haven Mineral Spring.	Hubbardston Magnetic Spring.	Lansing Magnetic Well.	Leslie Magnetic Wells.	Midland Magnetic Well.
Solids.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per imp. gallon.*[c]	*Grains per gallon.*[d]	*Grains per imp. gallon.*[e]
Sodium carbonate	2.09				
Sodium bicarbonate			112.08	5.27	
Potassium carbonate	2.74				
Potassium bicarbonate				4.55	
Calcium carbonate	2.01				
Calcium bicarbonate		23.81	107.59	30.62	
Magnesium carbonate	1.52				
Magnesium bicarbonate		10.71	23.03	10.53	
Iron carbonate	0.08				
Iron bicarbonate			1.88	2.27	
Sodium sulphate	71.29		30.06		22.07
Potassium sulphate			14.94		82.19
Calcium sulphate				7.04	4.46
Aluminium phosphate					1.73
Sodium chloride	306.03		320.22		32.70
Potassium chloride	1.93				
Calcium chloride	148.05				6.22
Magnesium chloride	71.53				2.19
Magnesium iodide	0.05				
Magnesium bromide	0.17				
Calcium fluoride	0.05				
Iron protoxide		0.16			
Alumina	0.30				
Silica	1.05	0.14	3.97	2.08	2.97
Organic matter				0.65	2.47
Loss					3.21
Total	608.89	34.82	613.77	63.01	160.21
Gas.			*Cubic inches.*	*Cubic inches.*	
Carbonic acid			235.55	13.5	

Constituents.	Mount Clemens Mineral Springs.			
	Mount Clemens Mineral Well.		Medea Spring.	Soolbad Spring.
Solids.	*Grains per gallon.*[f]	*Grains per gallon.*[g]	*Grains per gallon.*[f]	*Grains per gallon.*[f]
Calcium carbonate	0.98	3.98	91.00	Trace
Magnesium carbonate	0.70	Trace	0.70	Trace
Iron carbonate	5.60			
Sodium sulphate		77.25		
Calcium sulphate	100.56	35.20	14.30	44.00
Potassic salts		Trace	Trace	Trace
Sodic salts			11,741.00	
Calcic salts				11,181.00
Magnesic salts				
Iron sulphide		Trace		
Sodium chloride	11,900.00	8,637.44		
Calcium chloride	934.50	172.41		
Magnesium chloride	648.48	129.60		
Magnesium iodide	0.07			
Magnesium bromide	6.87			
Iron			8.50	Trace
Alumina	29.47	8.97	29.00	11.21
Silica	27.60		28.00	
Bromine			8.50	Trace
Iodine		0.82	0.07	0.05
Ammonia		Trace	Trace	Trace
Organic matter		Trace		
Total	13,654.33	9,065.17	11,921.07	11,236.26
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Hydrogen sulphide or dihydric sulphide	40.00	27.52	40.00	33.00
Carbonic acid	5.85	Trace		
Nitrogen	Present			

[a] C. G. Wheeler, analyst.
[b] P. H. Douglass, analyst.
[c] Dr. Jennings, analyst.
[d] R. C. Kedzie, analyst.
[e] S. P. Duffield, analyst.
[f] S. P. Duffield, analyst (1884).
[g] H. F. Meier, analyst.

Analyses of mineral springs in Michigan—Continued.

Constituents.	Owosso Chalybeate Spring.	Spring Lake Magnetic Well.	St. Clair Mineral Spring.	St. Louis Magnetic Spring.	Otsego Mineral Springs.
Solids.	*Grains (?) per gallon.*	*Grains per gallon.*[a]	*Grains per gallon.*	*Grains per imp. gall.*[b]	*Grains per gallon.*[c]
Sodium bicarbonate		0.05		106.40	
Calcium carbonate			0.15		
Calcium bicarbonate	25.67	0.13		69.40	14.29
Magnesium carbonate			1.10		
Magnesium bicarbonate	19.09	0.01		17.50	1.52
Iron bicarbonate	15.92	1.01		1.20	2.11
Manganese bicarbonate		0.05			
Sodium sulphate		46.70			
Potassium sulphate					1.15
Calcium sulphate			140.19	66.50	0.68
Calcium silicate				6.72	
Sodium chloride	2.10	405.53	9,565.01		1.65
Potassium chloride		4.29			
Calcium chloride		113.42	2,487.49		
Magnesium chloride		86.20	398.88		
Chloride				Trace	
Bromide		2.17			
Lithia		Trace			
Alumina	0.62	Trace	29.41		
Silica		0.50		2.88	
Silicates					2.80
Bromine			Trace		
Iodine			Trace		
Ammonia		0.02			
Organic matter		18.29		2.00	2.10
Loss					
Total	63.40	628.87	12,571.73	272.60	26.30
Gases.					*Cubic inches.*
Hydrogen sulphide or dihydric sulphide.			16.48	Trace	Trace
Carbonic acid				6.21	8.00

[a] C. G. Wheeler, analyst. [b] S. P. Duffield, analyst. [c] R. C. Kedzie, analyst.

Analyses of mineral springs in Michigan—Continued.

Constituents.	Ypsilanti Mineral Springs.			Warner's Spring.	Wyandotte White Sulphur Spring.
	Ypsilanti Well.	Moorman Well.	Owen's Mineral Well.		
	Grains per imp. gallon.[a]	*Grains per imp. gallon.*[b]	*Grains per imp. gallon.*[c]	*Grains per gallon.*	*Grains per imp. gallon.*[d]
Sodium carbonate					30.38
Calcium carbonate		63.73	57.91		44.30
Calcium bicarbonate	36.94			16.93	
Magnesium bicarbonate				4.70	
Iron bicarbonate				1.70	
Sodium sulphate				2.12	25.80
Potassium sulphate	18.62	42.40	36.87	0.82	Trace
Calcium sulphate	179.96	210.78	46.64	3.39	89.21
Magnesium sulphate	68.07	124.52	92.43		48.35
Phosphates	Trace	Trace	Trace		
Borates	Trace	Trace	Trace		
Lithium salts	Trace	Trace	Trace		
Strontium salts	Trace	Trace			
Barium salts	Trace	Trace	Trace		
Ferrous salts	Trace	Trace	Trace		
Sodium sulphide	12.19	10.12			
Sodium chloride	832.04	1,888.35	2,411.98	1.25	22.90
Potassium chloride					Trace
Calcium chloride		172.04	209.99		
Magnesium chloride	57.91	153.72	183.74		
Magnesium bromide	8.56	18.17	13.51		
Fluorides	Traces		Traces		
Iron oxide					0.25
Alumina				0.25	1.65
Silica	1.40			0.18	
Silicates			1.07		
Silicon dioxide		23.79			
Organic matter		Trace	Trace	1.02	
Loss					
Carbonic acid					30.50
Total	1,205.69	2,707.62	3,004.14	31.86	293.34
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Hydrogen sulphide or dihydric sulphide.	21.08	32.216	15.527		20.00

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[a] A. B. Prescott, analyst (1883).
[b] James H. Shepard, analyst.
[c] J. H. Shepard and W. F. Pett, analysts (1884).
[d] Courtis, analyst.

WISCONSIN.

The mineral waters of Wisconsin are valuable. Many of them have wide reputations and are largely sold in all portions of the country. They are principally alkaline, chalybeate, and calcic. The list is based mainly on the Wisconsin geological reports and has also had the supervision of Prof. T. C. Chamberlin, formerly State geologist. A number of springs have been developed since the publication of the State reports and are here included.

Mineral springs of Wisconsin.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Arctic Springs, Galesville, Trempealeau County.	3	...	...	...	Resort.
Artesian wells:					
In Madison, Dane County	4	...	53	Alkaline	Used for city supply.
In Oil City, Monroe County	1	...	52	Sulpho-chalybeate.	Not much used.
In Prairie du Chien, Crawford Co.	12	3,620	56	...	
In Fond du Lac, Fond du Lac Co.	...	...	...	...	
Barnes's Spring, Delavan, Walworth County.	...	...	...	...	
Bethesda Spring, Waukesha, Waukesha County.	1	4,200	48	Alkaline, calcic.	Used commercially and as a resort.
Black Earth Mineral Springs, Black Earth, Dane County.	2	...	44	Chalybeate, &c.	Do.
Bristol Soda Springs, Woodworth, Kenosha County.	...	...	...	Alkaline, saline	Unimproved.
Buckhert's Fountain, Watertown, Jefferson County.	1	700	47	...	Do.
Calcareous or travertine springs:					
In sections 6 and 7, Empire Township, Fond du Lac County.	...	...	...	Calcic	
At Lovers' Glen, Brooklyn Township, Green Lake County.	...	...	...	do	
At Delavan, Walworth Co	...	...	...	do	
In section 24, southwest quarter Hartford Township, Washington Co.	...	...	...	do	
In sections 11, 14, 15, Walworth Township, Walworth County.	...	...	...	do	
In section 21, Taycheedah Township, Fond du Lac County.	...	...	...	do	
In section 1, Whitewater Township, Walworth County.	...	...	...	do	
Cedarburg Springs, Cedarburg, Ozaukee County.	...	...	...	...	
Chalybeate springs:					
In Ahnapee Township, sec. 25, range 26 east, Kewaunee County.	...	...	...	...	
In Byron Township, sec. 16, southeast quarter, Fond du Lac Co.	...	...	...	...	
In Empire Township, sec. 18, northeast quarter, Fond du Lac Co.	...	...	...	...	
At Grande Chute, Walworth Co.	...	...	...	...	
In Herman Township, sec. 29, northeast quarter, Dodge County.	...	...	...	...	
In Hortonia Township, section 18, Outagamie County.	2	...	...	...	
In Lake Mills Township, section 1, north half, Jefferson County.	...	...	...	...	
In Whitewater Township, section 15, east quarter, Walworth Co.	...	...	...	...	
At Whitewater, Walworth Co.	...	...	...	...	
Clysmic Springs, Waukesha, Waukesha County.	...	...	...	...	
Crescent Spring, Waukesha, Waukesha County.	...	...	...	...	

Mineral springs of Wisconsin—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Eureka Springs, Milwaukee, Milwaukee County.	....	....	°	....	
Fountain Spring, Waukesha, Waukesha County.	....	....	......	....	
Gihon Springs, Delavan, Walworth Co.	8	....	46 to 56	Calcic, alkaline	Used commercially and as a resort.
Glenn Springs, Waukesha, Waukesha County.	2	45,000	48	Alkaline.......	Do.
Gomber's Well, Brodhead, Green Co	....	....	.....	....	
Hacket's Spring, Hale's Corners, Milwaukee County.	1	....	......	Calcic, alkaline	Unimproved; used locally.
Horeb Mineral Spring, Waukesha, Waukesha County.	1	1,500+	48	Alkaline, calcic	Used commercially and as a resort.
Hunter's Magnetic Mineral Fountain (artesian), Fond du Lac, Fond du Lac County.	....	......	......	....	
Hygeia Spring, Waukesha, Waukesha County.	....	....	......	....	
Iodo-Magnesian Springs, Beloit, Rock County.	4	10,000	47	Alkaline, calcic	Resort.
Jacob's Artesian Well, Milwaukee, Milwaukee County.	....	18,000	......	Calcic, saline...	
Jordan's Mineral Well (65 feet), Galesville, Trempealeau County.	1	....	......	Calcic, chalybeate.	
Lethean Spring, Waukesha, Waukesha County.	..	....	......	....	
Lowe's Spring (see Palmyra Springs).					
Magnetic Well, Watertown, Jefferson County.	...	....	......	....	
Market Square Spring, Milwaukee, Milwaukee County.	..	....	......	....	
Mineral Rock Spring, Waukesha, Waukesha County.	1	2,200	50	....	Used commercially and as a resort.
Mineral springs:					
At Kaukauna, Outagamie County..	..	....	......	Sulphureted	
Near Sussex, Waukesha County..	....	....	......	....	Unimproved; used locally.
At East Troy, Walworth County..	2	....	50	Calcic, alkaline	Used locally.
Mineral Spring Artesian Well, Oil City, Monroe County.	....	....	......	Sulpho-chalybeate.	
Nemahbin Mineral Springs, Delafield, Waukesha County.	...	....	......	....	
New Saratoga Springs, Star Prairie, Saint Croix County.	3	360	46	Chalybeate, carbonated.	Resort.
Norwalk Mineral Well, Norwalk, Monroe County.	....	....	......	Chalybeate	
Oakton Springs, Pewaukee, Waukesha County.	....	....	......	....	
Oleson's Sulphur Springs, La Grange Township, section 9, Walworth Co.	....	....	......	Sulphureted ...	
Park Spring, Lake Mills, Jefferson Co.	1	15	50	....	
Palmyra Springs, Palmyra, Jefferson County.	25	....	50 to 72	....	Used commercially and as a sanitarium.
Periclasian Spa Springs, Whitewater, Walworth County.	...	....	......	....	
Rahr's Artesian Well, Manitowoc, Manitowoc County.	1	130	......	Alkaline, calcic.	Unimproved.
Richmond Spring, Whitewater, Walworth County.	1	....	54	....	Used to some extent as resort.
Saint Croix Mineral Spring, near East Farmington, Polk County.	1	700	46	....	Used commercially and as a resort.
Schweickhardt's Spring, Wauwatosa, Milwaukee County.	....	....	......	....	
Shealtiel Mineral Springs, near Waupaca, Waupaca County.	2	200+	40	Alkaline	Do.
Sheboygan Mineral Spring (artesian), Sheboygan, Sheboygan County.	1	8,400	59	Saline, calcic....	Used commercially.
Sheridan Springs, Lake Geneva, Walworth County.	2	3,000	50 to 53	....do	Resort to a small extent.

Mineral springs of Wisconsin—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Siloam Springs, Waukesha, Waukesha County.	3	1,000+	° 48	....	Used commercially and as resort.
Silurian Spring, Waukesha, Waukesha County.	....	....	......	....	
Sparta Mineral Wells, Sparta, Monroe County.	12	....	50	Saline, chalybeate.	Used commercially.
Starin's Sulphur Spring, Whitewater Township, section 1, Walworth Co.	...	......	......	....	
Tellulah Mineral Spring (formerly Harriman's Spring), Appleton, Outagamie County.	1	? 400+	45	Saline	Used locally.
Utley Mineral Spring, Utley, Green Lake County.	1	10	......	....	Not yet improved.
Vesta Spring, Waukesha, Waukesha Co	1	1,200	47	Calcic, saline....	Used commercially.
Waterloo Mineral Well, Waterloo, Jefferson County.	....	......	......	....	
White Rock Spring, Waukesha, Waukesha County.	1	800	47	....	Do.
William's Sulphur Spring, La Grange Township, section 36, Walworth Co.	....	......	......	....	

Analyses of mineral springs in Wisconsin.

Constituents.	Arctic Springs.	Artesian Well, Madison.	Artesian Well (Wilds's), Fond du Lac.	Bethesda Spring, Waukesha.	
Solids.	*Grs. per gall.*[a]	*Parts in* 1,000.[b]	*Parts in* 1,000.[b]	*Parts in* 1,000.[b]	*Grs. per gall.*[c]
Sodium bicarbonate	....	0.04	....	0.02	1.26
Calcium bicarbonate	13.65	0.14	0.11	0.17	17.02
Magnesium bicarbonate..	9.84	0.12	0.08	0.13	12.39
Iron bicarbonate	0.26	0.01	....	....	0.04
Sodium sulphate	0.07	0.03	0.07	0.02	0.54
Calcium sulphate	....	....	0.01	....	....
Potassium sulphate	0.19	....	....	....	0.46
Sodium phosphate	....	....	....	....	Trace
Sodium chloride	0.76	0.01	0.07	0.01	1.16
Calcium chloride	0.05	....	....	....	....
Aluminium oxide	0.15	....	....	....	0.12
Silica....................	0.06	0.03	0.01	0.01	0.74
Organic matter..........	....	....	....	....	1.98
Total..............	25.03	0.38	0.35	0.36	35.71

Constituents.	Black Earth Mineral Springs.	Bristol Soda Springs.	Buckhert's Fountain.		Madison City Well.
Solids.	*Parts.*[d]	*Grs. per gall.*[e]	*Grs. per gall.*[f]	*Grs. per gall.*[g]	*Grs. per gall.*[h]
Sodium carbonate	5.10	....	....	....	....
Sodium bicarbonate	....	8.89	1.90	....	1.09
Calcium carbonate	40.00	....	....	....	....
Calcium bicarbonate	....	4.36	12.09	12.04	15.24
Magnesium carbonate....	25.00	....	....	....	....
Magnesium bicarbonate..	....	3.21	5.82	7.94	12.98
Iron carbonate	12.00	....	....	....	....
Iron bicarbonate	....	0.49	0.10	0.08	0.21
Sodium sulphate	10.00	7.74	....	0.86	0.29
Potassium sulphate	0.10	....	0.05	....	0.24
Sodium phosphate	....	....	....	....	Trace
Sodium chloride..........	3.30	0.43	....	0.66	0.29
Aluminium oxide	1.00	....	....	0.16	Trace
Silica....................	1.30	0.80	0.30	0.68	0.42
Organic matter...........	Trace	....	0.35	....	....
Total	([i])	25.92	20.61	22.42	30.76

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[a] W. W. Daniels, analyst.
[b] G. Bode, analyst.
[c] C. F. Chandler, analyst.
[d] A. C. Barry, analyst.
[e] A. G. Mariner, analyst.
[f] L. Brandecke, analyst.
[g] G. Bode, analyst (1878).
[h] W. W. Daniels, analyst (1882).
[i] Incomplete.

Analyses of mineral springs in Wisconsin—Continued.

Constituents.	Clysmic Springs.			Eureka Springs.	Fountain Spring.	Gihon Springs.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Parts in 1,000.*[c]	*Grains per gallon.*[d]	*Parts in 1,000.*[e]
Sodium bicarbonate	1.26	4.431	0.803	0.12	1.02	....
Calcium bicarbonate	16.04	16.153	15.896	0.41	13.78	10.27
Magnesium bicarbonate	13.56	9.221	8.540	0.18	9.20	7.14
Iron bicarbonate	0.04	0.572	0.685	....	0.05	0.20
Sodium sulphate	0.56	0.693	1.076	0.26	0.36	0.95
Potassium sulphate	0.46	0.500	0.205	....	....	....
Sodium phosphate	0.03	0.429	0.453	....	....	....
Sodium chloride	1.17	0.355	0.548	3.35	Trace	0.47
Aluminium oxide	Trace	....	....	0.19	0.09	0.13
Silica	0.72	0.802	0.810	0.12	0.55	0.75
Alumina	....	Trace	Trace	....	....	....
Organic matter	1.62	Trace	Trace	....	0.31	....
Total	35.46	33.156	29.016	4.64	25.36	19.91

Constituents.	Glenn Springs.	Gomber's Well.	Hacket's Spring.	Horeb Mineral Spring.	Hunter's Magnetic Mineral Fountain.	Hygeia Spring.
	Grains per gallon.[f]	*Grains per gallon.*	*Grains per gallon.*[g]	*Grains per gall.*[e]	*Parts in 100.*[h]	*Grains per gall.*[i]
Sodium carbonate	....	....	....	....	4	....
Sodium bicarbonate	0.76	0.03	0.46	....	....	2.26
Calcium carbonate	....	....	....	....	5	....
Calcium bicarbonate	15.98	6.66	8.41	10.75	....	16.73
Magnesium carbonate	....	....	....	....	6	....
Magnesium bicarbonate	11.58	4.86	3.23	6.88	....	13.14
Potassium carbonate	....	....	....	....	4	....
Iron bicarbonate	0.09	0.23	0.36	....	....	0.58
Sodium sulphate	0.62	0.17	1.04	1.25	18	0.52
Calcium sulphate	....	....	....	....	12	....
Magnesium sulphate	....	....	....	....	17	....
Potassium sulphate	0.49	....	....	....	10	0.82
Sodium phosphate	Trace	....	....	....	....	0.04
Sodium chloride	1.19	0.32	0.24	0.18	14	1.25
Potassium chloride	....	....	....	....	3	....
Aluminium oxide	0.05	0.13	0.11	0.23	....	0.72
Silica	1.05	0.69	0.87	0.73	5	0.15
Iron	....	....	....	....	Trace	....
Bromine	....	....	....	....	Trace	....
Organic matter	2.21	0.18	....	....	....	Trace
Loss	....	....	....	....	7	....
Total	34.02	13.27	17.72	20.02	[j] 100	36.21

Constituents.	Iodo-Magnesian Springs.	Jacob's Artesian Well.	Jordan's Mineral Well.	Lethean Spring.	Magnetic Well, Watertown.
	Grs. per gall.[f]	*Grs. per gall.*[e]	*Grs. per gall.*[c]	*Parts in 1,000.*[c]	*Parts in 1,000.*[e]
Sodium bicarbonate	0.14	....	0.89	0.02	....
Calcium bicarbonate	14.52	8.69	6.50	0.17	0.19
Magnesium bicarbonate	12.28	6.63	8.16	0.11	0.13
Iron bicarbonate	0.04	0.13	2.67	Trace	Trace
Sodium sulphate	....	8.86	1.97	0.02	0.02
Calcium sulphate	0.13	14.55	....	....	0.01
Potassium sulphate	0.31	....	....	....	....
Sodium phosphate	0.01	....	....	....	....
Sodium chloride	0.34	0.64	0.18	0.01	Trace
Potassium chloride	....	0.27	....	....	....
Sodium bromide	Trace	....	....	....	....
Sodium iodide	Trace	....	....	....	....
Aluminium oxide	0.06	0.19	0.68	Trace	Trace
Silica	0.76	2.38	0.29	0.01	0.02
Organic matter	Trace	....	0.48	....	....
Total	28.59	42.34	21.82	0.34	0.37

Rathbone, analyst.

[b] Ogden Doremus, analyst (1883).

[c] G. Bode, analyst.

[d] J. V. Z. Blaney, analyst (1873).

[e] G. Bode, analyst (1874).

[f] C. F. Chandler, analyst (1875).

[g] G. Bode, analyst (1879).

[h] E. J. Gillett, analyst.

[i] A. Thiel, analyst.

[j] There are 19 grains per gallon.

Analyses of mineral springs in Wisconsin—Continued.

Constituents.	Market Square Spring, Milwaukee.	Mineral Spring, East Troy.	Mineral Rock Spring.	Nemahbin Mineral Springs.	New Saratoga Springs.
	Parts in 1,000.[a]	*Parts in* 1,000.[b]	*Parts in* 1,000.[c]	*Parts in* 1,000.[a]	*Grs. per gall.*[d]
Sodium bicarbonate	0.04		0.02	0.02	0.81
Calcium bicarbonate	0.37	0.21	0.17	0.21	4.00
Magnesium bicarbonate	0.36	0.14	0.14	0.09	3.07
Iron bicarbonate				Trace	0.74
Sodium sulphate	0.03	0.02	0.02	0.02	0.08
Calcium sulphate	0.16				
Sodium chloride	0.43	0.01	0.01	0.02	0.13
Potassium chloride	0.03				
Aluminium oxide				Trace	
Silica	0.04	0.02	0.02	0.02	1.04
Organic matter			Trace		
Total	1.46	0.40	0.38	0.38	9.87

Constituents.	Palmyra Springs.				
	Lowe's Springs.		Bidwell Spring.	Zenobia's Fountain.	Eye Spring.
	Spring No. 1.	Spring No. 2.			
	Grains per gallon[a]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Grains per gallon.*[e]	*Grains per gallon.*[e]
Sodium bicarbonate	1.28	1.23	1.57	0.18	0.16
Calcium bicarbonate	12.72	12.22	9.01	12.85	9.86
Magnesium bicarbonate	5.77	5.54	6.48	10.14	7.92
Iron bicarbonate			0.33		0.06
Sodium sulphate	1.19	1.14	0.28	0.40	0.64
Calcium sulphate				0.79	0.30
Sodium chloride	1.27	1.22	0.33	0.43	0.21
Iron oxide	Trace	Trace			
Aluminium oxide			Trace	0.22	0.19
Silica	1.11	1.08	0.73	0.91	0.61
Organic matter					0.35
Total	23.34	22.43	18.73	25.92	20.30

Constituents.	Oakton Springs.	Rahr's Artesian Well.	Richmond Spring.	St. Croix Mineral Spring.	Schweickhardt's Spring.
	Parts in 1,000.[f]	*Parts in* 1,000.[a]	*Parts in* 1,000.[g]	*Grains per gallon*[h]	*Parts in* 1,000.[a]
Sodium bicarbonate	0.01		0.04	0.79	0.01
Calcium bicarbonate	0.24	0.43	0.45	11.19	0.21
Magnesium bicarbonate	0.22		0.33	7.25	0.15
Iron bicarbonate	0.01		0.01		0.01
Sodium sulphate	0.01	0.64	Trace	0.52	0.01
Calcium sulphate		0.99			
Magnesium sulphate		0.83			
Potassium sulphate			0.02		
Sodium chloride	Trace		0.02	0.05	Trace
Potassium chloride		0.01			
Calcium chloride		0.38	0.03		
Aluminium oxide	Trace		Trace	[i]0.49	
Silica	0.01	0.02	0.02	0.27	0.03
Organic matter	Trace		0.04	Trace	Trace
Total	0.50	3.30	0.96	20.56	0.42

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[a] G. Bode, analyst.

[b] G. Bode, analyst (1869?).

[c] G. Bode, analyst (1872).

[d] G. Bode, analyst (Sept. 9, 1875).

[e] G. Bode, analyst (1884).

[f] J. V. Z. Blaney, analyst (1872).

[g] J. E. Garner, analyst (1873).

[h] J. V. Z. Blaney, analyst (1877).

[i] With iron.

Analyses of mineral springs in Wisconsin—Continued.

Constituents.	Shealtiel Mineral Springs.	Sheboygan Mineral Spring.		Sheridan Springs.	Siloam Springs.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[e]	*Grains per gallon.*[b]	*Parts in 1,000.*[b]
Sodium bicarbonate	0.76				0.02
Calcium bicarbonate	6.44	1.49	13.66	12.55	0.22
Magnesium bicarbonate	6.36	0.38		10.28	0.13
Iron bicarbonate	0.05		0.50	0.11	
Manganese bicarbonate			0.17		
Sodium sulphate	0.19			0.30	0.05
Calcium sulphate		76.15	169.83	1.43	
Magnesium sulphate		89.33			
Barium sulphate			Trace		
Iron sulphate		0.74			
Calcium phosphate			0.04		
Sodium biborate			Trace		
Sodium chloride	0.16	367.65	306.94	0.31	0.02
Potassium chloride			14.48		
Calcium chloride		109.80	27.83		
Magnesium chloride		9.91	54.91		
Lithium chloride		0.02	0.10		
Sodium bromide		1.06	0.19		
Sodium iodide		0.02	Trace		
Aluminium oxide	0.09	1.10	0.13	0.05	
Silica	0.60	0.78	0.47	0.73	0.01
Organic matter			Trace	0.23	
Total	14.65	657.88	589.25	25.99	0.45

Constituents.	Silurian Spring.	Sparta Mineral Wells.		Tellulah or Harriman's Mineral Springs.	Vesta Spring.
		Magnetic Well.	Artesian Well.		
	Grains per gallon.[d]	*Grains per imp. gallon.*[c]	*Parts in 1,000.*[b]	*Parts in 1,000.*[b]	*Grains per gallon.*[b]
Sodium carbonate		0.21			
Sodium bicarbonate	0.03			0.05	0.41
Calcium carbonate	9.93	0.40			
Calcium bicarbonate			0.07	0.08	13.43
Magnesium carbonate	6.83	4.03			
Magnesium bicarbonate			0.01	0.06	10.74
Barium carbonate		0.01			
Strontium carbonate		0.02			
Lithium carbonate		0.03			
Ammonium carbonate		Trace			
Iron carbonate	0.13	14.84			
Iron bicarbonate			0.01	Trace	0.05
Manganese carbonate		Trace			
Sodium sulphate	0.29	2.21		0.02	0.55
Calcium sulphate		0.18			
Magnesium sulphate			0.04		
Potassium sulphate		0.64			
Sodium phosphate		0.06			
Aluminium phosphate		0.06			
Iron phosphate	Trace				
Manganese phosphate	Trace				
Hydric sulphide		Trace			
Sodium chloride	0.19	0.14	0.01	0.01	0.30
Calcium chloride		0.61	0.01		
Sodium iodide		Trace			
Aluminium oxide	0.59				0.13
Silica	0.70	0.28	0.01	0.02	0.85
Organic matter	Trace			Trace	
Total	18.69	23.22	0.16	0.24	26.46

[a] G. Bode, analyst (1884).
[b] G. Bode, analyst.
[c] C. F. Chandler, analyst (1876).
[d] Walter S. Haines, analyst (1880).
[e] J. M. Hirsh, analyst (1876).

Analyses of mineral springs in Wisconsin—Continued.

Constituents.	Waterloo Mineral Well.	White Rock Spring.		Utley Mineral Spring.	Artesian Mineral Well, Prairie du Chien.	Park Spring.
	Parts in 1,000.[a]	*Grains per gallon.*[a]	*Grains per imp. gallon.*[b]	*Parts in* 100.[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium bicarbonate		1.18	1.28			
Calcium				.0063440		
Calcium carbonate					0.6222	
Calcium bicarbonate	0.24	11.72	17.67			1.5470
Magnesium				.0036072		
Magnesium carbonate					10.9739	
Magnesium bicarbonate	0.28	5.31	13.02			1.3238
Iron bicarbonate			0.27		0.2318	0.1298
Sodium sulphate		1.09	1.09		12.7978	
Magnesium sulphate	0.21					
Potassium sulphate			0.82			
Calcium sulphate					15.3699	
Sodium nitrate	0.64					
Sodium chloride	0.42	1.17	1.12		90.2007	
Calcium chloride	0.51					
Magnesium chloride	0.13					
Lithium chloride	0.02					
Potassium chloride					3.8064	
Sodium bromide					0.1281	
Sodium phosphate					Trace	
Aluminium oxide			0.75			
Silica	9.02	1.04	1.04	Undetermined	2.8430	0.8106
Alumina				.0004110	0.0610	0.0467
Iron				Undetermined		
Sodium				Trace		
Chlorine				.0005000		
Sulphuric acid				.0013100		
Carbonic acid				.0118600		
Organic matter					Trace	
Total	11.47	21.51	37.06	.0240322	137.0348	3.8579

[a] G. Bode, analyst.

[b] I. Campbell Brown, analyst (1874).

[c] C. Dwight Marsh, analyst (1885).

[d] G. Bode, analyst (1876).

[e] Prof. Daniels, analyst.

MINNESOTA.

The list of Minnesota springs has been compiled almost entirely from Prof. N. H. Winchell's reports on the geology and natural history of the State. No previous list credits the State with any mineral springs. In fact they are only beginning to attract attention. Although several have some local reputation, as yet only two are utilized to any considerable extent as resorts, and the water of only one is found on sale. Two salt wells have been developed in the extreme northwestern part of the State, and they have been included in the list. Big Stone Lake, which is an expansion of Minnesota River, has also been included, as the analysis shows that the water contains a large amount of sulphates and considerable silica.

Mineral springs of Minnesota.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Big Stone Lake, Big Stone County			°	Saline	
Bryan's Mineral Spring, near Minnesota City, Winona County.	1			Calcic	Local reputation.
Calcareous springs:					
In section 22, Osborne Township, Pipe Stone County.				Calcic	
Near mouth of Big Stone Lake, Big Stone County.				Calcic	
Carbureted springs:					
Near Freeborn and Alden, Freeborn Co.					
Chalybeate springs:					
On south branch of Cottonwood, near Amiret, Lyon County.					
In sec. 16, Holly Township, Murray Co.					
In Home Township, Brown County					
In sec. 14, Kiester Township, Faribault County.					
At southwestern end of Lake Benton, Lincoln County.					
At western end of Lake Benton, Lincoln County.	2				
In sec. 5, Otisco Township, Waseca Co.					
In sec. 9, Otisco Township, Waseca Co.					Do.
In sec. 22, Manyaska Township, Martin County.					Do.
At Schwartz Lime-Kiln, Ottawa Township, Le Sueur County.					
In Stately Township, Brown County					
In sec. 30, Swedes Forest Township, Redwood County.					
Chalybeate and sulphur springs:					
In Murray County, three miles south of Walnut Grove.					
Geisinger Spring, Rochester, Olmsted Co.	1		45		Local resort.
Humboldt Salt Well, Kittson Co					
Inglewood Springs, Minneapolis, Hennepin County.	3	150		Alkaline	Used commercially
Mineral springs:					
In Pope County				Chalybeate	
Mineral Well, Tracy Station, Lyon County	1			Saline	
Owatonna Mineral Springs, near Owatonna, Steele County.	9			Alkaline, calcic	Resort.
Salt Lake, Mehurrie (?) Township, Lac-qui-Parle County.				Alkaline	
Saint Vincent's Salt Well, Saint Vincent, Kittson County.					
Sulphur Springs, section 20, Eden Township, Pipe Stone County.	2				

Analyses of mineral springs in Minnesota.

Constituents.	Owatonna Mineral Springs.		Bryan's Mineral Spring.	Inglewood Springs.
	Vichy Spring.	Name unknown.		
	Grains per gallon.[a]	*Grains per gallon.*	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Sodium carbonate	52.41			
Sodium bicarbonate		1.86		
Calcium carbonate			10.62	9.[illegible]
Calcium bicarbonate	16.37	13.20		
Magnesium carbonate			6.08	4.69
Magnesium bicarbonate	8.40	5.29		
Potassium carbonate			0.09	
Iron bicarbonate	0.54	0.62		
Lithium carbonate			Trace	Trace
Calcium sulphate				0.12
Sodium sulphate	0.45	0.28	0.45	0.49
Potassium sulphate	0.28		0.04	0.17
Sodium chloride	0.84	0.17	0.03	0.07
Potassium nitrate			Trace	
Calcium nitrite				Trace
Iron oxide			0.14	0.01
Alumina	0.10	0.28		
Manganese bicarbonate	Trace			
Sodium phosphate	Trace			
Calcium phosphate				Trace
Sodium iodide	Trace			
Organic matter	Trace	Trace		
Phosphates			Traces	
Silica	1.79	1.12	0.95	1.22
Free carbonic acid	4.34			
Total	85.02	22.82	18.40	16.56

Constituents.	Well at Tracy Station.	Big Stone Lake.	Humboldt Salt Well.
	Grains per gallon.[d]	*Grains per gallon.*[e]	*Grains per gallon.*[e]
Sodium carbonate	Trace		
Calcium carbonate	41.25	6.44	
Magnesium carbonate	14.70	3.67	78.60
Iron carbonate		0.13	1.08
Calcium sulphate			116.08
Sodium sulphate	97.58	5.58	
Magnesium sulphate		8.64	71.12
Potassium sulphate		0.73	
Magnesium chloride			91.44
Sodium chloride	Trace	0.88	2,764.99
Calcium chloride			42.26
Potassium chloride			156.55
Iron protoxide	0.66		
Alumina			2.38
Silica	2.27	6.21	12.15
Total	156.46	32.28	8,336.65

[a] Enno Sander, analyst (1875).
[b] William A. Noyes, analyst (1882).
[c] William A. Noyes, analyst (1883).
[d] G. A. Mariner, analyst.
[e] James A. Dodge, analyst (1884).

DAKOTA.

Information as to mineral waters in Dakota is meager and the data obtained are insufficient for the compilation of a very complete list of the springs and wells that are known to be mineralized. The Territory has not been sufficently developed to have much attention directed to the subject. In some of the southeastern counties are springs and wells in which the water is said to be chalybeate, but correspondence with persons in that section does not develop much in relation to them beyond the fact that they are unimproved. There are said also to be salt wells in the northeastern part of the Territory. In various portions, also, alkali is quite abundant in the soil, and in such regions the water passing through it is naturally alkaline. Such localities are found along the Little Missouri River near the crossing of the Northern Pacific Railroad and in the vicinity of the Black Hills. Newton and Jenney, in their report on the geology of the Black Hills, say: "Springs issuing from the black clay shales of the Cretaceous on Beaver Creek were found to be strongly acid and astringent to the taste, turning blue litmus red and probably containing alum and free sulphuric acid. Similar springs were reported to be found near Buffalo Gate, on the southeastern side of Black Hills." Springs in the Carboniferous rocks of this region are naturally hard, but would scarcely be classed with mineral springs. The Chicago and Northwestern Railroad Company have had a number of wells and springs on the line of their road analyzed, and several of them are mineralized. These have been included in the list and the analyses are given in the table following the list.

Mineral springs of Dakota Territory.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.*	Remarks.
Aberdeen Artesian Well, Aberdeen, Brown County.					
Acid springs:					
On Beaver Creek, Custer, Custer Co.					
Near Buffalo Gate, Custer, Custer Co.					
At Devil's Lake, Ramsey County				Saline	
Artesian wells:					
At Clark Centre, Clark County				Calcic	
At Devil's Lake, Ramsey County				Sulphur, chalybeate.	
At Saint Lawrence, Hand County				Saline	
Dakota Hot Springs, Hot Springs, Fall River County.					Resort.
Dunseith Mineral Spring, Dunseith, Rolette County.	1				
Gary Mineral Spring, Gary, Deuel Co.	1				
Mineral springs or wells:					
In Bon Homme County				Chalybeate	
In Fall River County					
In Turner County				Chalybeate	
Near Ree Heights, Hand County					
On Medicine Creek, 30 miles east of Pierre, Hughes County.				Saline	
Near Missouri River, at Pierre, Hughes County.				Alkaline, saline	
At foot of Bluff at Pierre, Hughes Co.				Saline	
On west shore of Big Stone Lake, Grant County.				Chalybeate, calcic, sulphur.	
Salt springs:					
Near Grafton, Walsh County					
Near Pembina, Pembina County					Unimproved.
Sulphur Springs, Devil's Lake, Ramsey Co.	2				
Wamduska Lake, Wamduska, Nelson Co.	1			Saline	
Wessington Springs, Wessington Springs, Jerauld County.	3			Chalybeate and sulphureted.	Resort.

Analyses of mineral springs in Dakota Territory.

Constituents.	Artesian wells.			Mineral Springs or wells.		
	At Aberdeen.	At Clark Centre.	At Saint Lawrence.	Medicine Creek Spring.	Well at foot of bluff at Pierre.	Well near river at Pierre.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[b]	*Grains per gallon.*[b]
Silica	0.9911	1.63	1.99	3.47	1.53	1.33
Iron oxide	0.0349					
Iron protoxide			4.07	0.74	Trace	
Alumina	0.0816				0.01	0.19
Calcium carbonate	1.4157	9.68	47.14	8.42	31.31	9.20
Calcium bicarbonate	18.7245					
Sodium carbonate		1.21	3.34	Trace	0.54	
Magnesium carbonate	0.0611	0.11		3.93	6.57	2.89
Sodium chloride	38.8609	0.19		8.89	4.33	1.26
Magnesium chloride			38.06			
Potassium sulphate	17.7780					
Calcium sulphate		1.76	4.56			
Sodium phosphate	Trace					
Sodium sulphate	49.4604		168.54	38.92	133.76	
Soda						21.24
Volatile matter	0.8123					
Total	128.2205	14.58	267.70	64.37	178.05	25.61

[a] Erastus G. Smith, analyst (1885).

[b] G. A. Mariner, analyst.

IOWA.

Mineral springs are not of common occurrence in Iowa, although many wells, both artesian and ordinary, are frequently mineralized. Neither Walton nor Moorman mentions any of the springs of the State. The present list is mainly the result of direct correspondence with the different spring-owners and local authorities. The springs are of the same general character as in the adjoining States. The occurrence of acid springs is interesting from a geological point of view. Colfax Mineral Spring is probably the most widely known of the places of resort.

Mineral springs of Iowa.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks.
Acid Spring, at coal mine on Bluff Creek, Monroe County.					
Artesian wells:					
At Webster City, Hamilton County	6				
At Farmington, Van Buren County					
At Harper's Ferry, Allamakee Co.					
At Keokuk, Lee County					
Seven miles below Davenport, Scott County.					
At Dubuque, Dubuque County				Slightly sulphureted.	
At Lansing, Allamakee County					
At McGregor, Clayton County					
Chamberlain (or Storm Lake) Mineral Springs, Storm Lake, Buena Vista Co.	3	2,000	48	Saline	Local resort.
Cherokee Magnetic Mineral Springs, Cherokee, Cherokee County.					Used commercially and as a resort.
Colfax Mineral Springs, Colfax, Jasper County.	8	960	52	Saline, chalybeate.	Do.
Dunbar's Mineral Spring, near College Springs, Page County.	1	100	56	Calcic	Sold to limited extent and used as a resort.
Big Mineral Spring and Flowing Wells, Rosenkrans Park, Webster City, Hamilton County.	5	6,400	83		Used locally.

Mineral springs of Iowa—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Gypsum Spring, Fort Dodge, Webster County.	......	....	....	Alkaline	
Henryson's Artesian Well, Story City, Story County.	......	....	....	Chalybeate	Unimproved.
Iowa Acid Spring, Eddyville, Wapello County.	2	....	....	Acid...........	Local reputation.
Kinersly's Well, 1 mile from Keosauqua, Van Buren County.	......	....	..	....do	
Linwood Spring, Linwood, Scott Co ..	1	30,000	56	....	Resort
Magnetic Spring, Lehigh, Webster Co.	......	....	....	....	Used locally.
Maulsby's Spring (well), 3 miles north of Dexter, Dallas County.	1	400+	..	Saline	Local reputation.
Mineral springs:					
At Fellow's Grove, Carroll County	......	....	....	....	
At Iowa City, Johnson County .	......	....	..	....	
Near Big Spring, Wayne County..	......	....	....	....	Unimproved.
Mineral Wells (artesian), north of Ames, Story County.	16	....	47	Chalybeate . .	Unimproved, one is supposed to have medicinal effects.
Ottumwa Medical Springs, Ottumwa, Wapello County.	1	40	54	Alkaline, saline	Used as a resort and commercially.
Phœnix Mill Sulphur Spring, Davenport, Scott County.	......	....	..	....	
Prospect Park Mineral Springs, Des Moines, Polk County.	......	......	....	... .	
Siloam Springs, Iowa Falls, Hardin Co.	2	420	48	Alkaline, calcic.	Sanitarium.
Sulphur and Iron Wells, Howard Co .	......	....	....	....	
Sulphur Springs, Sulphur Springs, Buena Vista County	2	....	....	Sulphur	
Watkins's Artesian Well, Story City, Story County.	......	....	....	Carbureted and calcic.	Unimproved.

Analyses of mineral springs in Iowa.

Constituents.	Colfax Mineral Springs (Old M. C Spring).	Dunbar's Mineral Spring.	Iowa Acid Spring.	Artesian Well, Farmington.	Mineral Spring, Fellow's Grove.
	Grains per gallon. [a]	*Grains per gallon.* [b]	*Grains per gallon.* [c]	*Grams per liter.* [d]	*Grams per liter.* [d]
Magnesium carbonate....	....	3.81	....	....	....
Calcium carbonate	17.51	8.41	....	....	....
Iron carbonate	0.67	3.57	....	....	....
Sodium sulphate	78.86	....	0.37	....	....
Potassium sulphate	0.41	....	....	....	....
Magnesium sulphate. ..	31.87	3.76	13.86	....	....
Calcium sulphate	13.07	....	44.65	....	....
Iron sulphate	....	1.14	97.30	....	....
Sodium chloride..........	3.85	2.84	....	....	....
Magnesium chloride	....	....	0.82	....	....
Magnesium bromide	....	Trace	....	....	....
Calcium oxide...........	....	....	....	0.44	0.43
Iron oxide..............	....	....	....	....	0.04
Magnesium oxide	....	....	....	0.18	0.24
Sodium silicate..........	....	....	15.89	....	....
Silica	0.29	0.59	....	....	....
Alumina		....	226.41	....	....
Sulphuric acid	....	....	408.99	1.33	1.56
Lithia	Trace	....	....	....	....
Carbon dioxide..........	7.18	....	....	....	....
Ammonium crenate	....	....	8.10	....	....
Organic matter	....	1.27	Traces	....	....
Phosphoric acid	....	Trace	....	....	....
Hydrochloric acid	....	....	....	0.23	....
Iron	....	....	....	0.02	....
Insoluble...............	....	....	....		....
Total................	153.71	25.39	816.39	2.20	2.29
Gas.		*Cubic inches.*			
Carbonic acid	....	42.30	....	....	....

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[a] G. Hinrichs, analyst. [b] J. H. Wright, analyst. [c] J. H. Seibel, analyst (1882). [d] Rush Emery, analyst.

Analyses of mineral springs in Iowa—Continued.

Constituents.	Gypsum Spring, Fort Dodge.	Artesian Well, Harper's Ferry.	Artesian Well, near Davenport.	Chamberlain or Storm Lake Mineral Springs.	Cherokee Magnetic Mineral Springs.
	Grams per liter.[a]	*Grams per liter.*[a]	*Grams per liter.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Magnesium carbonate			0.02		8.21
Calcium carbonate			0.02		5.93
Lime				14.46	
Iron carbonate					11.26
Sodium bicarbonate					0.01
Sodium carbonate			0.29		0.31
Sodium				0.47	
Sodium sulphate			0.49		0.87
Potassium				1.35	
Magnesia				6.13	
Iron phosphate					0.73
Chlorine				0.11	
Sodium chloride			0.14		
Magnesium oxide	0.07	0.04			
Calcium oxide	0.45	0.10			
Oxygen				0.41	
Silica			[d]0.06	3.56	0.82
Alumina					0.29
Sulphuric acid	1.06	0.08		25.02	
Organic matter				2.50	
Hydrochloric acid		0.10			
Iron and alumina oxides				0.18	
Carbonic acid for magnesia.				5.51	
Hydrogen for the magnesia.				0.25	
Total	1.58	0.41	1.02	59.95	27.93
Gas.					*Cubic inches.*
Carbonic dioxide					59.30

Constituents.	Ottumwa Medical Springs.	Henryson's Artesian Well.	Watkins's Artesian Well.	Siloam Springs.
	Grs. per gall.[e]	*Gms. per liter.*[f]	*Gms. per liter.*[f]	*Grs. per gall.*[g]
Magnesium carbonate	30.80	0.1134	0.1246	
Calcium carbonate	22.26	0.1910	0.1990	
Iron carbonate	2.94			
Sodium bicarbonate				2.5003
Sodium		0.0417	0.1155	
Calcium bicarbonate				18.1116
Magnesium bicarbonate				10.2316
Protoxide of iron bicarbonate				0.0702
Sodium sulphate	200.88			0.4270
Potassium sulphate	2.23			
Calcium sulphate	88.23			
Sodium chloride	51.81	0.0016		0.0750
Silica	7.30	Trace	0.0250	0.8290
Alumina	Trace			0.1170
Organic matter	Trace			Trace
Iron and alumina oxides		0.0135	0.0060	
Loss		0.0008	0.0009	
Total	356.45	0.3620	0.4710	32.3617

[a] Rush Emery, analyst.
[b] Walter L. Brown, analyst.
[c] John W. Draper, analyst (1881).
[d] With loss.
[e] James Carter, analyst (1883).
[f] F. W. Clarke, analyst (1885).
[g] Gustavus Bode, analyst.

MISSOURI.

This State is rich in mineral springs, which are of great variety. Only about one-fifth of them are improved, but among the latter are several that are well known throughout the State.

As far as known the springs are very similar to those of the neighboring States, saline, sulphureted, and chalybeate springs predominating.

Many of the counties have salt springs or wells, and at one time the production of salt from them was a considerable industry. The list of springs given here has been compiled mainly from the State geological reports and from various hand-books. The present status of the various springs has been determined, whenever practicable, by direct correspondence with the spring-owners.

Mineral springs of Missouri.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alum wells:			°		
In section 3, township 32, range 29, Barton County.	....	....	......	....	
In section 35, township 33, range 29, Barton County.	....	....	......	....	
In section 28, township 33, range 33, Barton County.	...	....	......	....	
In Milford, Barton County	....	....	......	....	
Arlington Springs, 8 miles south of Marshall, Saline County.	20	....	65	Saline, sulphureted, &c.	
Arnica Springs, near Stockton, Cedar County.	....	....	......	....	
Aurora Springs, Aurora Springs, Miller County.	8	300	......	Saline	Resort.
Belcher's Artesian Well (2,199 feet), Saint Louis, Saint Louis County.	1	....	73 to 74	... do	
Bethesda Springs, near Stockton, Cedar County.	....	....	......	....	
Big Salt Springs, West of Marshall, Saline County.	....	....	60	Sulpho-saline ...	
Blankenship's Medical Springs, 2½ miles north of Houston, Texas Co.	100	2,000+	59 to 75	....	Do.
Boone's Lick, Boonesborough, Howard County.	....	....	......	....	
Bowsher Mineral Spring, 1½ miles north of Princeton, Mercer County.	....	200+	50	Chalybeate	Do.
Bratton Spring, near Columbia, Boone County.	....	....	......	....	
Buffalo Spring, near Louisiana, Pike County.	....	....	......	....	
Burkhart's Spring, 2 miles west of Franklin, Howard County.	....	....	......	....	
Cedar Springs, 7 miles east of Eldorado Springs, Cedar County.	7	200	47	Chalybeate	Do.
Chalybeate springs:					
On Hog and Hazel Creeks, Adair County.	....	....	......	....	
East of Butler, Bates County	....	....	......	....	
In section 9, township 33, range 28, Cedar County.	....	....	......	....	
In section 22, township 34, range 28, Cedar County.	....	....	......	....	
At Dripping Spring, Boone Co...	....	....	......	....	
At Twin Springs, Boone (?) Co..	....	....	......	....	

Mineral springs of Missouri — Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Chalybeate springs — Continued.			°		
Near Mount Moriah, Harrison Co.					
Six miles north of Knobnoster, Johnson County.					
Ten miles south of Warrensburg, Johnson County.					
In section 12, township 62, range 10 west, Knox County.					
At Lexington, La Fayette County.					
On Bryant's Creek, Lincoln Co.					
Near Louisville, Lincoln County.					
West of Sharpsburg, Marion Co.					
At Jacksonville, Randolph Co.					
In section 34, township 64, range 21, Sullivan County.					
West of Osceola, Saint Clair Co.					
Near Smithton, Worth County.					
Choteau Springs, 10 miles from Boonville, Cooper County.	4	600	58		Has local reputation, but no improvements at present.
Cheltenham Springs, Cheltenham (?), Saint Louis County.					
Clark's Sulphur Springs, 5 miles from Warsaw, Benton County.					
Climax Springs, Climax, Camden Co.	7		58 to 59	Saline	Resort.
Cole's Springs, Marshall, Saline Co.	4			Saline, sulphureted, chalybeate.	Do.
Columbia Chalybeate Springs, Boone County.					
Copperas or Sweet Sulphur Springs, Sec. 33, T. 51, R. 2 W., Lincoln Co.	2	90	60		Unimproved.
Crystal Springs, McDonald County.					
Davis's Sulphur Springs, Piko Co.					
Dawson's Springs, East of Osceola, Saint Clair County.					
Dixon Springs, Cureall, northwest of West Plains, Howell Co.	50	1,800+			Resort and used commercially to some extent.
Eldorado Springs, Eldorado Springs, Cedar County.	8	180+			Used as a resort and commercially.
Eldorado Springs, section 1, township 21, range 5 west, Oregon Co.	50	500+		Chalybeate	Resort.
Elk Springs, Elk Lick Springs, Pike County.	3			Saline?	Summer resort.
Ellis Well, near Nevada, Vernon Co.					
Excelsior Springs, Excelsior Springs, Clay County.	4			Saline	
Fairview Mineral Spring, Denver, Worth County.	1		50	Chalybeate, saline.	Resort.
Fike's Lick Spring, 2 miles from Elk Lick Springs, Pike County.	1			Saline?	Unimproved.
Ford Springs, on Big Ransom, Pike County.					
Gorham's Lick, Randolph County.					
Hagenbush Spring, Cabool, Texas County.	1				Do.
Harriman's Sulphur Spring, Cooper County.			58		Do.
Houtze's Sulphur Springs, section 1, township 36, range 29, Vernon Co.					
Hunter's Epsom Well, Nevada, Vernon County.					
Indian Springs, Indian Springs, McDonald County.	4	48	57 to 67½		Resort to a limited extent.
Jericho Springs, Jericho, Cedar Co.	2	100			Local resort.
Landreth's Mineral Well, Knox City, Knox County.		1		Saline, chalybeate.	Resort.
Le Outre Lick Springs, west of Danville, Montgomery County.					

Mineral springs of Missouri—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Lewis Spring, 1½ miles from Glasgow, Howard County.					
Lindsay's Lick, near junction of Big and Little Ramsey, Pike County.					
Louis Spring, Greenfield, Dade Co	1			Chalybeate	Resort.
McAllister Springs, on Blackwater Creek, Saline County.					
Meramec Springs, near Nasby, Saint Louis County.					
Merriwether's Epsom Springs, Pike County.					
Mineral Springs, Panacea, Barry Co					Do.
Mineral springs:					
Six miles east of Cassville, Barry County.					
In section 18, township 40, range 32, Bates County.				Saline	
In section 22, township 40, range 29, Bates County.				do	
In Elston, Cole County				Sulphureted, saline.	
Near Elston, Cole County					
Two miles from Knobnoster, Johnson County.				Alkaline	
Three miles northwest of Warrensburg, Johnson County.					
Near Spring Hill, Livingston Co				Saline, sulphureted.	
One and one-half miles from Lane's Prairie, Maries County.					
In McDonald County					
On Blackwater Creek, near Tenny Creek, Saline County.			51		
Near Houston, Texas County					
Eight miles southeast of Marshall, Saline County.	4				
Near Glasgow, Howard County	2				
Mineral Well, west of Crescent Hill, Bates County.				Saline	
Mint Spring, 5 miles northeast of Hartville, Wright County.					
Monagaw Sulphureted Springs, 10 miles from Osceola, Saint Clair Co.					
Montesano Springs, near Sulphur Springs Landing, Jefferson County.	10	150	60	Saline, sulphureted.	Used commercially and as a resort.
Mooresville Mineral Springs, Mooresville Livingston County.				Calcic, saline	Resort and used commercially.
Nevada Mineral Springs, Nevada, Vernon County.	3	825	47	Sulphureted	Resort.
New Baden Springs, 12 miles west of Kirksville, Adair County.	5	500+	62	Alkaline, calcic.	Once a resort, now unimproved.
Osceola Springs, ½ mile from Dripping Spring, Boone County.					
Paris Chalybeate Springs, Paris Springs, Lawrence County.	3	250+	50	Chalybeate	Resort.
Quitman Red Sulphur Springs, near Quitman, Nodaway County.					
Randolph Medical Springs, Medical Springs, Randolph Co.	2	2,200+	52 to 54		Used commercially and as a resort.
Reiger Spring, Mercer County, near Lineville, Iowa.	1	40	50	Saline	Resort and used commercially to some extent.
Rocheport Sulphur Springs (or Adams Springs), Rocheport, Boone County.	4			Sulpho-saline	Local resort.
Salt Springs, Salt Springs, Saline Co.					
Saratoga Springs, Saratoga, McDonald County.					
Siloam Springs, Siloam Springs, Howell County.	15		50 to 68	Alkaline, saline.	Resort.

Mineral springs of Missouri—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Spaulding Springs, Ralls County, 12 miles southwest of Hannibal.	4	2,400		Saline, chalybeate.	Resort.
Stice's Spring, ½ mile from Dripping Spring, Boone County.					
Saint Louis Artesian Well (3,843 feet), Insane Asylum, Saint Louis, Saint Louis County.	1		105	Saline, calcic	
Sulphur Springs, Sulphur Springs Landing, Jefferson County.	3	100	45		Once used as a resort.
Sulphur springs:					
In section 27, township 34, range 30, Vernon County.					
In section 16, township 35, range 29, Vernon County					
One-half mile north of Wright City, Warren County.					
In Marion County					
In eastern part of Bates County					
In Benton County					
Two miles from Elston, Cole Co.					Unimproved.
In Cooper County					
Near Fayette, Howard County				Saline, sulphureted.	Do.
In section 33, township 49, range 15, Howard County.					
Near Franklin, Howard County					
In Jefferson County					
On Cuivre River, Lincoln County					
On Lick Creek, northwest of Ely, Marion County.					
In section 6, township 53, range 1 west, Pike County.					
At Saverton, Ralls County					
Trabues Lick, near Spencer Creek, Ralls County.					
In section 33, township 56, range 5 west, Ralls County.					
On Davis Creek, Saline County					
Five miles west of Osceola, Saint Clair County.					
Twenty miles from Saint Louis, Saint Louis County.					
In section 23, township 34, range 30, Vernon County.					
Sulphur Well, section 18, township 40, range 32, Bates County.					
Sweet Springs, near Huntsville, Randolph County.					
Sweet Springs, near Brownsville, Saline County.	5	224,000+	54	Saline	Used commercially and as a resort.
Twin Springs, McDonald County					
White Sulphur Springs, 15 miles northeast of Osceola, Saint Clair Co.					
White Sulphur Springs, 8 miles from Warsaw, Benton County.					
Zodiac Springs, Zodiac, Vernon County.	12		48 to 52	Saline, chalybeate.	Resort.

Analyses of mineral springs in Missouri.

Constituents.	Aurora Springs.	Boone's Lick.	Bowsher Mineral Spring.	Bratton Spring.	Burkhart's Spring.
	Grs. per gall.	*Grs. per gall.*[a]	*Grs. per gall.*[b]	*Grs. per gall.*[c]	*Grs. per gall.*[a]
Calcium bicarbonate			5.5980		
Magnesium bicarbonate			0.9089		
Iron carbonate	5.130				
Ferrous bicarbonate			4.7639	2.63	
Manganese bicarbonate			0.0655		
Sodium sulphate			0.2208		
Calcium sulphate	2.427	119.27		64.19	135.08
Magnesium sulphate			0.2286	15.73	
Potassium sulphate			0.7445		
Aluminium tersulphate				52.45	
Ferrous sulphate				36.74	
Calcium phosphate			0.0245		
Sodium chloride	4.009	972.29	1.0973	1.31	1,082.48
Calcium chloride		81.47			93.74
Magnesium chloride	6.949				116.89
Aluminium oxide			0.6484		
Lithia	1.430				
Ferrous oxide	0.933				
Silica			4.7896	2.53	
Carbonic acid				11.95	
Free carbonic acid			3.0541		
Total	20.878	1,173.03	22.1441	187.53	1,428.19

Constituents.	Choteau Springs.	Columbia Chalybeate Springs.	Climax Springs.	Ellis Well, Nevada.	Alum Well, Milford.
	Parts in 1,000.[d]	*Grs. per gall.*[e]	*Grs. per gall.*[f]	*Grs. per gall.*[a]	*Grs per gall.*[a]
Calcium carbonate	0.173			6.80	
Calcium bicarbonate		14.52			
Magnesium carbonate	0.036			7.76	
Iron carbonate	0.009				
Iron bicarbonate		5.51			
Sodium sulphate		16.22			63.81
Calcium sulphate	0.665	95.78		5.85	43.44
Magnesium sulphate		31.34			66.66
Sodium chloride	6.632			30.19	
Calcium chloride	0.566			9.91	
Potassium chloride	0.085				
Magnesium chloride	0.648			8.62	
Calcium oxide			4.98		
Magnesium oxide			1.80		
Aluminium oxide		0.79	[g]5.08		
Silica	0.008	1.46			
Sulphuric acid			3.60		
Carbonic acid	0.185	15.52	8.92		
Sodium			14.00		
Potassium			1.20		
Iodine Bromine			14.00		
Chlorine			20.40		
Organic matter		0.07			
Loss			3.02		
Total	9.007	181.21	72.00	69.13	173.91

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[a] Regis Chauvenet, analyst.
[b] Paul Schweitzer, analyst.
[c] Paul Schweitzer, analyst (1874).
[d] Litton, analyst (1853).
[e] Paul Schweitzer, analyst (1873).
[f] H. W. Wiley, analyst (1882).
[g] With iron oxide.

Analyses of mineral springs in Missouri—Continued.

Constituents.	Fairview Mineral Spring.	Harriman's Sulphur Spring.	Landreth's Mineral Well.	Sweet Springs near Brownsville.	
				Akesion Spring.	Sweet Spring.
	Grs. per gall.[a]	*Parts in* 1,000.[b]	*Grs. per gall.*[c]	*Grs. per gall.*[d]	*Grs. per gall.*[d]
Calcium carbonate		0.122	32.65	40.25	9.56
Calcium bicarbonate	14.88				
Magnesium carbonate		0.055			
Magnesium bicarbonate	16.98				
Iron carbonate		0.006	2.39	0.27	0.57
Iron bicarbonate	18.73				
Manganese carbonate				0.20	Trace
Sodium sulphate			30.86	2.61	
Calcium sulphate	11.60	1.590	18.41	57.93	9.46
Magnesium sulphate			23.54		
Potassium sulphate			0.47		
Barium sulphate				8.15	
Calcium phosphate				0.24	
Magnesium nitrate				0.18	
Ammonium nitrate				1.17	
Sodium chloride	2.64	15.757	1.17	756.11	86.92
Calcium chloride		1.826		74.79	14.72
Potassium chloride		0.014		28.56	3.40
Magnesium chloride		1.403		87.32	22.29
Lithium chloride				0.30	0.05
Magnesium bromide				0.18	0.12
Aluminium oxide			0.67	0.17	0.09
Silica		0.010	0.95	0.51	1.08
Carbonic acid		0.298	7.56		
Free carbonic acid	4.56				
Organic matter				3.05	4.01
Total	69.39	20.581	118.67	1,061.94	152.27

Constituents.	Mooresville Mineral Springs.	Lewis Spring.	New Baden Springs.	Prewett's Well.
	Grs. per gall.[e]	*Grs. per gall.*[f]	*Grs. per gall.*[e]	*Grs. per gall.*[f]
Calcium carbonate		23.71		13.93
Calcium bicarbonate	17.61		20.05	
Magnesium carbonate		73.12		
Magnesium bicarbonate			2.36	
Iron bicarbonate	5.07		0.31	
Manganese bicarbonate			0.11	
Sodium sulphate			7.48	
Calcium sulphate	4.66	122.91	28.06	22.28
Magnesium sulphate	1.40			20.37
Potassium sulphate			1.23	
Aluminium sulphate	5.20			
Calcium phosphate			0.04	
Sodium chloride	2.15	951.80	0.05	7.70
Calcium chloride		37.29		
Potassium chloride	2.45			
Aluminium oxide			0.22	
Silica	0.61		1.54	
Free carbonic acid			12.75	
Iodine	Trace			
Organic matter	2.15			
Loss	0.22			
Total	41.52	1,208.83	74.20	64.28

[a] Lord and Stoutenburg, analysts.
[b] Litton, analyst.
[c] Paul Schweitzer, analyst.
[d] Charles P. Williams.
[e] Wright and Merrell, analysts (1881).
[f] Regis Chauvenet, analyst.

Analyses of mineral springs in Missouri—Continued.

Constituents.	Randolph Medical Springs.	Belcher's Artesian Well.	Paris Chalybeate Springs: Williams's Spring.	Montesano Springs.	
				Montesano Spring.	Casco Spring.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Parts in 1,000.*[b]	*Grains per gallon.*[c]	*Grains per gallon*[c]
Calcium carbonate		10.63	0.300	71.450	69.970
Magnesium carbonate		1.02	0.024	14.050	15.500
Iron carbonate	5.13	0.52	0.006		
Sodium sulphate			0.065		
Calcium sulphate	2.43	45.67	0.855	32.370	33.930
Magnesium sulphate			0.037		
Potassium sulphate			0.037		
Iron and alumina				0.870	0.750
Sodium hyposulphite				0.747	0.649
Calcium phosphate				Trace	Trace
Sodium sulphide				0.339	0.432
Sodium chloride	4.01	350.61		365.110	368.210
Calcium chloride		27.58			
Potassium chloride		9.01		16.370	16.990
Magnesium chloride	6.95	38.34	0.023	35.910	34.410
Magnesium bromide				Trace	0.107
Magnesium iodide				0.852	
Lithia	1.43				
Ferrous oxide	0.93				
Silica		0.14	0.013	0.510	0.670
Carbonic acid			0.239		
Total	20.88	483.52	1.099	538.578	541.618
Gases.		*Cubic inches.*		*Cubic inches.*	*Cubic inches.*
Carbonic acid		6.56		46.43	43.20
Sulphureted hydrogen		0.24		1.40	1.60

Constituents.	Montesano Springs.			
	Council Spring.	Alton Spring.	Pearl Spring.	Thorn Spring.
	Grains per gallon.[c]	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[c]
Magnesium carbonate		5.540		
Magnesium bicarbonate	3.770			
Calcium carbonate		48.100		
Calcium bicarbonate	39.720		57.920	62.440
Calcium sulphate	31.910	38.980	38.490	34.560
Sodium hyposulphite	Trace	Trace	Trace	
Sodium chloride	272.150	337.570	362.520	365.520
Potassium chloride	11.680	13.050	13.870	15.280
Magnesium chloride	30.990	35.490	46.230	47.500
Calcium chloride			3.880	7.220
Sodium sulphide		1.560		
Sodium bisulphide	1.974		1.644	1.736
Magnesium bromide	0.347	0.147	0.879	0.409
Magnesium iodide	Trace		0.024	0.112
Calcium phosphate		Trace	Trace	Trace
Silica	0.770	0.710	1.250	0.840
Iron and alumina	0.460	0.540	0.370	0.380
Volatile suspended matter			2.560	
Mineral suspended matter			1.800	
Total	393.771	481.687	530.937	535.997
Gases.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	34.30	40.03	44.14	43.24
Sulphureted hydrogen	1.43	1.98	1.76	1.59

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[a] Paul Schweitzer, analyst.
[b] Litton, analyst.
[c] Potter and Riggs, analysts.

NEBRASKA.

The data at hand in relation to Nebraska are insufficient for any extended list of its mineral springs or wells. Springs of any kind are of comparatively infrequent occurrence in most portions of the State, and especially so in the western part.

In many places the waters reached by wells are doubtless somewhat mineralized, as in the neighboring State of Kansas and in Dakota. Salt springs are found in the southeastern part of the State and also near the Elkhorn and Loup Rivers. There is a saline artesian well at Lincoln. So far as can be learned, none of the springs or wells is used medicinally at present.

Mineral springs of Nebraska.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Artesian Well, Lincoln, Lancaster County	1	......	......	......	
Saratoga Sulphur Spring, Saratoga, Holt County	1	......	......	......	
Salt Springs, Lincoln, Lancaster County	......	......	......	......	

KANSAS.

Permanent springs of any kind are said to be somewhat infrequent in Kansas. The mineral waters of the State are derived principally from ordinary wells and artesian borings. Salt or brine wells are quite common in certain portions of the State and are extensively used for the production of salt for local use. Chalybeate springs are found in various places, but the mineral waters are mainly saline and sulpho-saline. They have been developed to a certain extent and many of them have considerable local reputation for medicinal effects. Prof. E. H. S. Bailey, writing of the artesian wells of the State, in the Report of the Kansas State Board of Agriculture for the quarter ending December 31, 1885, says that "shallow wells, especially in the eastern part of the State, furnish hard water impregnated with sulphate of lime and carbonates of lime and magnesia; and as the well goes into deeper strata the chlorides increase and the sulphates decrease."

Among the places of resort the Great Spirit Spring, Baxter Medical Springs, and Geuda Springs are well known.

The list of springs given here is probably incomplete and will doubtless be considerably enlarged in the future.

Mineral springs of Kansas.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alma Salt Well, Alma, Wabaunsee County.	......	....	° 48	....	
Arrington Mineral Springs, Arrington, Atchison County.	3	420	60	Carbonated, saline, chalybeate.	Used commercially and as a resort.
Baxter Medical Springs, Baxter Springs, Cherokee County.	2	450	50	Chalybeate	Do.
Bonner's Springs, Tiblow, Wyandotte County.	20+	....	....	Calcic, carbonated.	Resort.
Brom-magnesian Mineral Well, Independence, Montgomery Co.	1	....	62	....	
Cranmer Springs, Conway Springs, Sumner County.	8	3,000	43½ to 50	....	
Flowing spring, 2 miles southwest of Junction City, Davis County.	.... .	....	....	....	
Fort Scott Artesian Well, Fort Scott, Bourbon County.	1	416	67½	Sulpho-saline ...	
Geuda Springs, Geuda Springs, Sumner County.	7	1,500	55 to 61	Saline	Used commercially and as a resort.
Girard Mineral Well, Girard, Crawford County.	......	....	....	....do	Local resort.
Great Spirit Spring, Cawker City, Mitchell County.	1	.. ..	....	.. do	Resort.
Haddon Mineral Well, Moss Springs, Davis County.	.....	....	....	Saline ?	
Henek's Mineral Springs, Arrington, Atchison County. (*See* Arrington Springs.)					
Iola Mineral Well, Iola, Allen County.	1	120	61	Saline	Used as a sanitarium and resort and commercially.
Jordan's Springs, Jordan Springs, Reno County.	24	1,800+	56 to 57	.. do	Unimproved.
Lee's Springs, 6 miles east of Peabody, Marion County.	4	350	....	....	
Louisburg Gas Wells, Louisburg, Miami County.	3	....	....	....	
Louisville Springs, Louisville, Pottawatomie County.	3	....	64	Chalybeate	Resort.
Manhattan or Kansas Artesian Mineral Wells, 10 miles from Manhattan, Riley County.	2	800+	56	Saline	Used commercially and as a resort.
Mineral Spring, Atchison, Atchison County.	......	....	....	....	Has local reputation.
Moodyville Mineral Springs, 4 miles south of Blaine, Pottawatomie County.	......	....	....	Alkaline, &c	Resort.
Mound Valley Spring, Mound Valley, Labette County.	1	....	....	....	
Murphy's Seven Springs, 7 miles from Junction City, Davis County.	7	....	....	Alkaline, calcic.	
Pfister's Mineral Spring, 6 miles from Junction City, Davis Co.	......	....	.. ..	....	
Piqua Mineral Wells, Piqua, Woodson County.	3	....	....	....	
Salt springs:					
In northeast part of Stafford County.	......	....	....	....	
In sections 14 and 15, township 8, range 7 west, Mitchell Co.	10+	100	....	....	
Sulphur springs:					
In section 35, township 7, range 2 west, Cloud County.	6	360+	47	Calcic	Unimproved.
In Allen County	......	....	....	....	
Tar Springs, near Somerset, Miami County.	6+	....	....	....	Used to limited extent as resort.
Wyandotte Gas Wells, Wyandotte, Wyandotte County.	6	....	....	....	

Analyses of mineral springs in Kansas.

Constituents.	Iola Mineral Well.	Fort Scott Artesian Well.	Manhattan Artesian Mineral Wells.		Baxter Medical Springs.	Murphy's Seven Springs.
			Well No. 1.	Well No. 2.		
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Calcium carbonate					8.89	
Calcium bicarbonate	60.89	14.23	5.28	6.07		13.128
Magnesium carbonate					0.12	
Magnesium bicarbonate	31.94	0.81				5.225
Lithium carbonate					0.40	
Iron carbonate					5.37	
Iron bicarbonate	3.93	1.00	0.19	0.25		
Sodium bicarbonate						3.470
Sodium sulphate		Trace				
Calcium sulphate		0.83	[f]33.87	14.69	8.86	
Magnesium sulphate			5.66	6.58	0.68	
Sodium chloride	980.50	79.47	0.52	0.86	0.20	
Magnesium chloride		7.99				
Calcium chloride		0.79				
Potassium chloride	17.91	Trace			0.11	
Lithium chloride		Trace				
Sodium biborate		2.20				
Silica	0.60	0.95	10.10	1.19	2.30	0.980
Organic matter	2.00	1.17				
Organic matter volatile and loss.					1.70	
Suspended matter	2.50					
Iodides	Traces					
Bromides	Traces					
Sodium hydrosulphide		0.19				
Potassium			Trace	Trace		
Sulphuric acid			61.36	33.11		
Chlorine			1.46	1.80		
Alumina and iron						Trace
Bromine			Trace			
Lithium			Trace			
Total	1,100.27	100.18	117.94	64.55	28.63	22.818
Gases.						
	Cub. inches.				*Cub. inches.*	
Carbonic acid	145.892	Trace			38.00	
Sulphureted hydrogen		Trace				

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[a] W. K. Kedzie, analyst (1876).

[b] E. H. S. Bailey and E. W. Walter, analysts (1884).

[c] G. H. Failyer, analyst.

[d] A. Morrill, analyst (1882).

[e] Barnes and Sim, analysts.

[f] With calcium chloride.

Analyses of mineral springs in Kansas—Continued.

Constituents.	Sulphur Springs, Cloud County.	Girard Mineral Well.	Heneck's Mineral Springs.		Arrington Mineral Springs.
			No. 1.	No. 2.	
	Grains per gallon.[a]	*Grains per imp. gallon.*[b]	*Grains per gallon.*[e]	*Grains per gallon.*[c]	*Grains per gallon.*
Sodium carbonate		10.528	11.456	3.551	
Calcium carbonate			9.763	6.612	5.336
Calcium bicarbonate	16.038	30.033			
Magnesium carbonate			5.928	3.257	3.566
Magnesium bicarbonate		17.360			
Potassium carbonate			1.435		
Iron carbonate			3.566	2.007	7.033
Lithium carbonate			0.416		
Iron protocarbonate		1.197			
Sodium sulphate		6.673	2.037		
Calcium sulphate	9.683		1.218		0.308
Magnesium sulphate	1.920		1.867		12.738
Potassium sulphate		1.031			
Sodium chloride		95.706	3.628	2.161	2.000
Magnesium chloride					1.110
Potassium iodide					Trace
Silica		1.190	0.987	0.555	0.540
Sulphuric acid	18.418				
Sodium	Trace				
Iron	Trace				
Ammonium crenate			0.818	Trace	
Lithia					Trace
Baregine					Trace
Organic matter			0.269	0.910	
Total	46.054	163.718	43.388	19.053	32.621
Gas.			*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid			42.00	39.30	94.30

Constituents.	Brom-magnesian Mineral Well.	Bonner's Springs.					
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	Grs. per gallon.[d]	*Grs. per gallon.*[e]	*Grs. per gallon.*[e]	*Grs. per gallon.*[c]	*Grs. per gallon.*[e]	*Grs. per gallon.*[e]	*Grs. per gallon*[e]
Sodium carbonate				66.481			
Calcium carbonate		11.248	13.424	7.028	11.674	13.392	7.968
Calcium bicarbonate	30.537						
Magnesium carbonate		5.472	Trace	7.482	1.961	2.335	5.846
Iron carbonate		1.871	0.141		6.594	4.947	5.771
Iron bicarbonate	1.682						
Calcium sulphate	9.047	2.608		Trace		0.344	0.604
Potassium sulphate	13.771						
Sodium chloride	3,466.921			12.768			
Magnesium chloride	347.770						
Calcium chloride	419.140	0.750	1.040		Trace	Trace	Trace
Sodium bromide	13.711						
Sodium iodide	0.092						
Phosphoric acid		Trace	Trace	Trace	Trace	Trace	Trace
Silica	1.155	0.495	0.380				
Alumina	Trace						
Organic matter	Trace	Sm'l am't	Sm'l am't	Sm'l am't	Trace		Sm'l am't
Total.	4,303.826	21.944	14.985	93.759	20.229	21.018	20.189
Gas.		*Cub. in.*	*Cub. in.*	*Cub. in.*	*Cubic in.*	*Cubic in.*	*Cubic in.*
Carbonic acid		25.660	16.190	21.716	19.032	20.069	18.422

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[a] G. H. Failyer, analyst.

[b] C. G. Gilbert, analyst.

[c] Juan H. Wright, analyst (1882).

[d] E. H. S. Bailey, analyst.

[e] William Jones, analyst (1884).

Analyses of mineral springs in Kansas—Continued.

Constituents.	Great Spirit Spring.	Flowing Spring.	Pfister's Spring.	Piqua Artesian Well.	Wyandotte Gas Wells.	Haddon Mineral Well.
	Grs per gallon.[a]	*Grs. per gallon.*[b]	*Grs. per gallon.*[b]	*Grs. per gallon.*[c]	*Grs. per gallon.*[d]	*Grs. per gallon.*[e]
Sodium carbonate		3.29				
Sodium bicarbonate	26.924			2.149		
Calcium carbonate		17.26	1.68		13.659	
Calcium bicarbonate				40.738		7.7605
Magnesium carbonate		5.48			86.661	
Magnesium bicarbonate				33.484		0.4463
Iron carbonate		1.65			1.400	
Iron bicarbonate				Trace		0.1946
Sodium sulphate	183.600		92.40			
Magnesium sulphate	85.281		58.24	6.000		
Calcium sulphate			44.80		0.525	
Sodium chloride	765.767		119.28	670.805	1,502.320	
Calcium chloride		Trace			56.103	
Potassium chloride				18.912		
Calcium oxide						8.6739
Magnesium oxide						9.7205
Sodium bromide	0.234					
Hydrogen sulphide (combined)						0.4967
Hydrogen sulphide (free)						1.9620
Silicious matter		0.95	6.72			
Carbonic acid (combined)						6.5886
Silicic acid	Trace					
Nitrous acid	Minute trace					
Boric acid						Trace
Sulphuric acid						37.4683
Phosphoric acid						Trace
Magnesium	27.561					
Calcium	31.398					
Alumina		0.21	1.12			1.4083
Sodium						3.1017
Silica				Trace	0.566	0.8774
Iodine						Trace
Lithia						Trace
Chlorine						0.8047
Organic matter					13.250	
Total	1,120.765	28.84	324.24	772.088	1,674.484	79.5037
Gas.	*Cubic in.*					
Carbonic acid	91.00			Abund't		

[a] G. E. Patrick, analyst (1880).

[b] Barnes and Sim, analysts (1883).

[c] E. H. S. Bailey, analyst.

[d] E. C. Franklin, analyst (1885).

[e] G. H. Failyer, analyst.

WESTERN STATES AND TERRITORIES.

The first thing to attract attention, in a general survey of the mineral springs of the West, is the far greater prevalence of thermal springs in them when compared with other sections. The Western States, as already defined, contain only a little over 39 per cent. of the total area of the country, and yet within their limits are found more than 80 per cent. of its known thermal springs. This proportion is likely to be increased, as the Western States present the best field for future discoveries. When we consider the individual springs, even manifestly imperfect as are our lists in respect to the total number, the contrast appears even greater. Not only is the number of hot and warm springs greatly in excess of that in other portions of the country, but the thermal phenomena are overwhelmingly greater in intensity. In no other section are there any manifestations equal to those exhibited by the geysers of the Yellowstone National Park.

Mr. G. K. Gilbert[1] has called attention to the fact that the geological relations appear to accord with this hydro-thermal contrast between the Western States and the other divisions of the country. He refers the greater heat in the former to local uprisings of the geiso-thermal planes, together with progressive corrugation, the intensity of the phenomena being heightened by the intrusion and extrusion of lavas.

The connection of hot and warm springs with volcanic rocks, with uplifted mountain chains, and with dislocations or fractures of strata has long been recognized. Our Western States present all these conditions. Here are the most elevated portions of our country and with the upward movement still in progress. A single glance at the general geologic map of the United States suffices to show that in this portion of our domain evidences exist of most intense volcanic activity, both past and present.

The Western States have been subdivided into four divisions, viz, the Rocky Mountain region, the Plateau region, the Great Basin, and the Pacific Coast. In the Rocky Mountain States, mountain corrugation is probably the primary cause of the hot springs found, although igneous areas are not wanting, as notably in the case of the Yellowstone National Park, in Wyoming. In the Pacific Coast region the uplifts of the Sierras and Coast Ranges are accompanied by igneous rocks, and as we proceed northward, volcanic outbursts form a striking feature. Almost all the springs on our Alaska list are warm or hot and in Alaska we find the volcanic forces still active.

In the Great Basin, mountain corrugation is subordinate to the faulting of the strata as a cause of hot and warm springs. Mr. I. C. Russell describes this region as follows:[2]

"The whole immense region lying between the Sierra Nevada and Rocky Mountain systems has been broken by a multitude of fractures, having an approximately north and south trend, that divide the region into long, narrow, orographic blocks."

With these profound faults hot springs are associated, and a map of the hot springs of the Great Basin would be, to a great extent, also a map of the lines of displacement. With these displacements also are associated volcanic rocks. In the plateau region again we find a similar association of faulted strata and the former outpouring of igneous rocks.

Although thermal springs are so characteristic of the Western States, other classes are not wanting. Alkaline, saline, chalybeate, and calcic springs are numerous; many of them are carbonated and still more are sulphureted. Silicious springs, not prominent in other sections, are found abundantly in the areas of hot springs.

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[1] Report of the United States Geographical Surveys West of the 100th Meridian, Vol. III, pp. 147-149.

[2] Fourth Annual Report of the United States Geological Survey, 1882-'83, p. 443.

The Western States having been more recently settled, we find that fewer springs have been improved and developed than in the east. Still the number of resorts is fairly large, and more waters are used commercially than would be expected in view of the newness of the country.

The number of analyses that have been made is, however, still comparatively small.

Summary for the Western States and Territories.

States.	Number of spring localities.	Number of individual springs.	Number of springs analyzed.	Number of springs utilized as resorts.	Number of springs used commercially.	Total number of analyses.
Montana	42	200	8	8	0	8
Idaho	32	114	2	4	0	2
Wyoming	41	2, 246	7	3	0	7
Utah	48	144	6	5	0	9
Colorado	70	359	37	16	1	38
New Mexico	36	126	12	5	2	12
Arizona	26	30	3	1	0	3
Nevada	120	179	4	10	0	6
California	220	435	44	42	11	44
Oregon	47	72	8	16	3	8
Washington	15	19	1	2	1	1
Alaska	25	25	0	0	0	0
Total	722	3, 949	132	112	18	138

MONTANA.

The Territory of Montana possesses many important and interesting mineral springs, although little has ever been published in relation to them, especially in general works on the subject. This is due partly to two causes: Montana was until recently so isolated that comparatively little was known of the Territory. Again, the proximity of the Yellowstone National Park and the fact that the readiest access to it is through Montana have attracted more attention to the wonderful phenomena of the geyser regions, and they have overshadowed the lesser springs. The majority of the springs are thermal, and they are found mainly in the western and more mountainous portions of the Territory. They are sulphureted, carbonated, alkaline, saline, chalybeate, and calcic. Among the carbonated springs is one closely resembling the celebrated Apollinaris spring of Prussia. Very few analyses have been made, and the character of more than half the springs is unknown. A number of localities have been improved and several are well known for the curative effects of their waters. Among the latter are the White Sulphur Springs, Hunter's Hot Springs, Matthews Warm Springs, and the Helena Hot Springs. The Territorial Asylum for the Insane is located at Warm Springs, in Deer Lodge County. The present table is derived from the personal knowledge of the writer, with data from various persons well known in Montana. Thanks are especially due to Mr. Peter Koch, of Bozeman, and Mr. Walter Matheson, of Billings, for information furnished.

Mineral springs of Montana.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alhambra Springs, Clancy, Jefferson County.			° Hot		Resort.
Allan's Mineral Springs, Pine Creek, Bitter Root Valley, Missoula Co.	16	500	114 to 121		Local resort.
Alum Spring, Upper Emigrant Gulch, Gallatin County.	1				Unimproved.
Bedford Warm Springs, Bedford, Jefferson County.					Do.
Big Hole Hot Spring, Big Hole Prairie, Beaver Head County.	100		132	Calcareous	Do.
Boulder Hot Spring, 2 miles from Boulder Valley, Jefferson County.					Local resort.
Bridger Cañon Tepid Spring, near Bozeman, Gallatin County.	1		80		Unimproved.
Chalybeate Spring, in Upper Emigrant Gulch, Gallatin County.					
Clark's Warm Springs, near Pony, Madison County.	8	2,000+	50 to 120		Unimproved but used locally.
Emigrant Gulch Warm Spring, on Emigrant Creek, Yellowstone Valley, Gallatin County.	1	14,400	102	Alkaline, calcic.	Used locally.
Grayson's Hot Springs, head of Deer Lodge Valley, Deer Lodge County.					
Hapgood Hot Springs, near Red Bluff, Madison County.	5				Unimproved.
Helena Hot Springs, near Helena, Lewis and Clarke County.	2		122 to 141	Alkaline, saline.	Improved.
Hot springs:					
On North Fork of Sun River, Lewis and Clarke county.				Sulphureted, chalybeate.	Unimproved.
Eighteen miles east of White Sulphur Springs, Meagher County.					
On Hellgate River, near Bear's Mouth, Deer Lodge County.					
Southwest of Flathead Lake and 14 miles northeast of Horse Plains, Missoula County.					
On Granite Fork of Lou-Lou Fork, Missoula County.					
Hunter's Hot Springs, Yellowstone Valley, Gallatin County.	12	105,000	122 to 141	Alkaline	Improved as a resort.
Livingston Warm Springs, near Livingston, Gallatin County.	12	24,000	104	Calcic, sulphureted.	Unimproved.
Lou-Lou Fork Hot Springs, on Lou-Lou Fork, Missoula County.		35,000	98? to 132	Chalybeate, sulphureted.	
Matthews Warm Springs, 7 miles west of Bozeman, Gallatin County.	2		114 to 122	Alkaline, saline	Improved.
Medicine Creek Hot Springs, on Weeping Child Fork of Bitter Root, Missoula County.					Used locally.
Miles City Artesian Well, Miles City, Custer County.				Alkaline	
Mill Creek Apollinaris Spring, Mill Creek, Yellowstone Valley, Gallatin County.			40	Carbonated	Unimproved.
Mineral springs:					
One mile north of Puller Springs, Madison County.					Do.
West Fork of Bitter Root River, Missoula County.				Carbonated	Do.
Nave's Warm Spring, on Crow Creek, Jefferson County.					Do.
Pipestone Springs, near Pipestone, Jefferson County.					

Mineral springs of Montana—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Puller's Springs, Puller Springs, on Upper Ruby Creek, Madison County.	2	....	° 102 to 110	....	Resort.
Ross's Hole Hot Springs, near head of Bitter Root River, Missoula County.	....	....	......	....	Unimproved.
Ryan's Hot Springs, Ryan's Cañon, near Dillon, Beaver Head County.	....	1,400	120	....	
Sulphur springs:					
On Deep Creek, between Townsend and White Sulphur Springs, Meagher County.	....	....	Cold.	....	Do.
On Rock Creek, northwest of Camp Baker, Meagher County.	....	....	......	....	
Near Great Falls of Missouri, Choteau County.	....	....	......	....	
Thermal springs:					
On Warm Springs Creek, near Moccasin Mountain, Meagher Co.	....	....	......	....	Unimportant.
At head of Big Spring Creek, Meagher County.	....	....	......	....	
Warm Springs, Warm Springs, Deer Lodge Valley, Deer Lodge County.	....	....	......	....	
Warm springs:					
On Warm Springs Creek, near Garrison, Deer Lodge County.	....	....	......	....	
Wasswieler's Warm Springs, near Helena, on Ten-Mile Creek, Lewis and Clarke County.	....	....	......	....	
Werner's Warm Springs, on branch of Crow Creek, Jefferson County.	....	....	......	....	
White Sulphur Springs, White Sulphur Springs, Meagher County.	9+	18,000+	128½	Alkaline and saline, sulphureted.	Resort.

Analyses of mineral springs in Montana.

Constituents.	Livingston Warm Springs.	Emigrant Gulch Warm Springs.	Helena Hot Springs.	Mill Creek Apollinaris Spring.
	Gram per liter.[a]	*Gram per liter.*[a]	*Gram per liter.*[a]	*Gram per liter.*[a]
Sodium carbonate	0. 0461	0. 0274	0. 1730	0. 9863
Calcium carbonate	0. 1880	0. 0865	0. 0268	0. 9270
Magnesium carbonate	0. 1533	0. 0269		0. 2868
Sodium sulphate		0. 0487	0. 2742	0. 9402
Calcium sulphate	0. 3150			0. 0204
Sodium chloride	0. 0143	0. 0058	0. 0596	0. 3795
Potassium chloride	0. 0078	0. 0088		0. 0961
Silica	0. 0290	0. 0317	0. 0938	0. 0250
Potassium			Trace	
Lithia			Trace	Trace
Iodine				Trace
Iron and aluminium oxide				0. 0876
Loss	0. 0040			0. 0656
Total	0. 7575	0. 2358	0. 6274	3. 8125

Constituents.	Hunter's Hot Springs.	Miles City Artesian Well.	White Sulphur Springs, Spring No. 2.	Matthews Warm Springs.
	Parts in 100, 000.[b]	*Grains per gallon.*[c]	*Gram per liter.*[d]	*Gram per liter.*[d]
Sodium carbonate	15. 05	60. 40	0. 5571	0. 0750
Calcium carbonate	0. 40	2. 27	0. 1280	0. 0390
Potassium carbonate	0. 55			
Magnesium carbonate	Trace		0. 0438	0. 0036
Iron carbonate	Trace			
Lithium carbonate	Trace			
Sodium sulphate	1. 04	1. 80	0. 4463	0. 1974
Sodium chloride	2. 47	2. 01	0. 2460	0. 0707
Potassium chloride			0. 0807	0. 0134
Silica	7. 74	1. 36	0. 0330	0. 0826
Free ammonia	0 43			
Albuminoid ammonia	0. 05			
Iron oxide		0. 54		
Magnesia		0. 83		
Potassium iodide	Trace			
Potassium bromide	Trace			
Sodium phosphate	Trace			
Sodium biborate	Trace			
Loss				0. 0010
Aluminium	0. 12			
Sodium silicate			0. 0194	0. 1098
Sodium sulphide	1. 46			
Hydrogen sulphide			Trace	
Total	29. 31	69. 21	1. 5543	0. 5925

[a] F. W. Clarke, analyst (1884).
[b] W. A. Noyes, analyst.
[c] J. M. Wing & Co., analysts (1884).
[d] R. B. Riggs, analyist (1885).

IDAHO.

The chemical composition of the mineral springs of Idaho is so little known that they cannot be definitely classified beyond stating that thermal springs predominate. That warm and hot springs abound might naturally be expected, when the geological structure of the Territory is recalled. Granitic and volcanic rocks prevail, and, in connection with the mountain corrugation, present most favorable conditions for the development of hot and warm springs. Mr. G. F. Becker, in the Statistics and Technology of the Precious Metals (p. 53), 1885, speaking of Idaho, says that hot springs are thickly distributed through the granitic areas, and in many cases issue directly through the granite, although usually within a mile or two of the known volcanic rocks, and that many of them are highly charged with alkalies and hydrogen sulphide. The list presented here has been made up largely from various maps. Mr. Albert Williams has also kindly given considerable information. Although few of the springs have been improved, a great many are used extensively for bathing, especially in the mining regions. The most widely known resort is at Soda Springs, near the bend of Bear River. None of the waters is at present used commercially.

Mineral springs of Idaho.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Bruneau Hot Spring, Bruneau Valley, Owyhee County.	1	70,000	° 105	....	Used for bathing resort.
Chalybeate Spring, near Spring Creek, of Henry's Fork, Oneida County.	1	....	Cold.	....	
Given's Hot Springs, Snake River, near Reynolds, Owyhee County.	2	2,000	98	....	Unimproved, but used to small extent locally for bathing.
Hot Creek, Idaho County, 20 miles northwest of Bonanza.	....	....	......	....	
Hot Creek, south of Snake River, 4 or 5 miles below American Falls, Oneida County.	....	....	......	....	
Hot lakes, 20 miles south of Washington, Idaho County.	....	....	......	....	
Hot springs:					
Five miles east of Boisé City, Ada County.	16	15,400	90 to 212	Chalybeate, alkaline, sulphureted, &c.	Improved and used as a resort.
North of Fishing Falls, Alturas County, about 60 miles southeast of Boisé City, 25 miles north of Snake River.	....	....	164	Chalybeate	Unimproved.
Fifteen miles west of Ketchum, Alturas County.	....	....	......	....	
Near Duck River, about 15 miles south of Hailey, Alturas County.	....	....	......	....	
Three miles southwest of Idaho City, Boisé County.	6	5,000	115	Sulphureted	Used locally.
On Salmon River, 15 miles south of Bonanza, Custer County.	....	....	......	....	
East side of Bear River, at south end of Gentile Valley, Oneida Co.	....	....	125	....	Unimproved.
On South Fork of Snake River, 8 miles below Salt River, Oneida County.	6	....	88 to 144	Saline and sulphureted.	Do.

Mineral springs of Idaho—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Hot springs—Continued.			°		
On South Fork of Snake River, below the lower cañon, Oneida Co.	1				Unimproved.
Lincoln Valley Warm Springs, 3 miles southeast of Fort Hall, Oneida Co.	5		60 to 87	Calcareous	Do.
Mineral springs:					
On Rapid River, Idaho County, 40 miles northwest of Bonanza.					
At Waha, Nez Percés County	10				
Robinson's Mineral Springs, Owyhee County.					
Soda Springs, at bend of Bear River, Oneida County.	40		52 to 88	Carbonated, calcareous, and chalybeate.	Improved as resort.
Twin or Soda Springs, east side of Portneuf Valley, Oneida County.					Unimproved.
Warm Creek, south of Salmon River, 20 miles south of Bonanza, Custer Co.					
Warm spring creeks:					
Southwest of Ketchum, Alturas Co					
Fifteen miles northeast of Banner, Boisé County.					
Six miles east of Challis, Custer Co.					
Warm springs:					
Near Munday's Ferry, on Snake River, Ada County.					
Southeast of Lemhi Agency, Lemhi County.					
Two miles north of Samaria, Oneida County.	1		85		
Seven miles south or southeast of Samaria, Oneida County.					
West side of Bear River, south end of Gentile Valley, Oneida Co.	5			Calcareous and chalybeate.	
On Lander road, northeast end of Upper Portneuf Valley, Oneida County.					
Warm Sulphur Springs, near Lincoln Lake, 13 miles south of Washington, Idaho County.				Sulphureted	

Analyses of mineral springs in Idaho.

These analyses are taken from Frémont's Report on an Exploration of the Country Lying Between the Missouri River and the Rocky Mountains, &c, Washington, 1843.

Constituents.	Soda Springs of Bear River, Beer Spring.	Deposit from Hot Springs, north of Fishing Falls.
	Grs. per gall.	*Per cent.*
Magnesium sulphate	48.40	
Calcium sulphate	8.48	
Calcium carbonate	15.44	14.60
Magnesium carbonate	12.88	1.20
Calcium chloride	5.82	
Magnesium chloride	4.48	
Sodium sulphate		[a]1.10
Sodium chloride	8.96	
Water and loss	3.40	5.20
Vegetable extractive matter		
Silica		72.55
Alumina		0.70
Iron oxide		4.65
Total	107.86	100.00

[a] With calcium sulphate.

WYOMING.

The Yellowstone National Park, with its wonderful geysers and large number of hot springs, lies almost entirely within the borders of Wyoming Territory. In the table the Park is divided into thirteen sublocalities, containing altogether more than two thousand springs. Besides these, our list includes twenty-eight localities outside of the Park. It is probably not complete, for there are large portions of the Territory still but little known. This is especially true of the region of the Big Horn Mountains. The table has been compiled from various Government maps and reports. Several places are utilized as resorts, and the water from a spring at Soda Butte in the National Park is sometimes offered for sale in Montana.

Mineral springs of Wyoming.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	**Remarks.**
			°		
Alkali lakes, on branches of Lost Creek, south of Sweetwater Mountains, Sweetwater County.	......	......	....	....	
Calcareous Springs, Green River, 10 miles south of the Upper Bend, Uinta County.	......	......	....	....	
Chalybeate springs:					
Three miles northwest of Point of Rocks, Sweetwater County.	......	......	....	....	
Near Meeteetse, south of Grey Bull River, Frémont County.	......	......	50	....	
Hot springs:					
On Beaver Creek, northwest of Rongis, Frémont County.	......	......	96	....	
At Hot Spring gate on North Platte River, Carbon County.	......	......	....	....	
On Big Horn River, Sweetwater ? or Johnson County.	......	......	....	....	
Two miles from Camp Brown, Frémont County.	......	......	110.8	....	
On Snake River, 4 or 5 miles below Hoback's River, Uinta (?) County.	......	......	117	Calcic	
Hot sulphur springs:					
On Stinking Water River, 20 miles east of Heart Mountains, Sweetwater County.	......	......	....	....	
On west side of Salt River, 5 miles northeast of Oneida Salt Works, Uinta (?) County.	......	......	....	....	
Le Roy Springs, near Le Roy Station, Uinta County.	12	......	....	Carbonated, saline.	Used locally.
Saratoga Springs, Saratoga, Carbon County.	6	600	120	Saline, chalybeate.	Resort.
Soda Lakes, along Sweetwater River, Carbon and Sweetwater (?) Counties.	......	......	....	....	
Sulphur springs:					
On Sulphur Creek, near Hilliard, Uinta County.	......	......	....	....	
On Hoback's River, 5 miles above mouth, Uinta (?) County.	......	......	47	....	
Near junction of North and South Forks of Stinking Water River, Sweetwater (?) County.	......	......	56	....	
Four or 5 miles east of North and South Forks of Stinking Water River, Sweetwater County.	......	......	....	....	
Six miles west of Camp Brown, Frémont County.	......	......	50	....	

Mineral springs of Wyoming—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Sulphur springs—Continued.			°		
East of Point of Rocks, Sweetwater County.	......	......	....	....	
East of Rock Springs, Sweetwater County.	......	......	....	....	
Near Rawlins, Carbon County...	......	......	....	....	
At Sulphur, south of Separation, near Bridger Pass, Carbon Co.	7	......	....	....	Unimproved.
Sulphur and chalybeate springs, valley of Medicine Bow River, Carbon County.	......	......	....	....	
Warm springs:					
Northwest of Fort Laramie, Laramie County.	1	......	74	....	
Fifteen miles north of Independence Rock, on Horse Creek, Carbon County.	......	......	....	....	
Wind River, below Warm Spring Creek, Frémont (?) County.	......	......	84	....	
Mouth of Jake's Creek Cañon, near Wind River, Frémont (?) County.	......	......	68	....	
Yellowstone National Park springs:					
Mammoth Hot Springs	78	......	63 to 165	Saline, calcic ...	Improved for a resort.
Yellowstone River Springs......	47	......	127 to 196	Sulphureted, acid, and silicious.	
Hayden's Valley Springs	128	......	190 to 197	... do	
Yellowstone Lake Springs.......	112	......	190 to 192	Silicious and sulphureted.	
Pelican Creek Springs...........	11	....	160	Sulphureted, &c.	
Gibbon River Springs	121	......	90 to 197	Silicious, &c	
Lower Geyser Basin.............	693	......	180 to 201	....do	Accommodations for tourists.
Upper Geyser Basin	440	......	190 to 200	....do	Do.
Third Geyser Basin	20	......	185 to 192	... do	
Shoshone Geyser Basin..........	356	......	192 to 201½	....do	
Heart Lake Geyser and Basin...	149	......	175 to 198	....do	
Lewis Lake and Snake River....	40	......	112 to 174	....do	
Sulphur Springs on Cascade Creek	.....	......	....	Sulphureted	

Analyses of mineral springs in Wyoming.

Constituents.	Yellowstone National Park Springs.						Le Roy Springs.
	Mammoth Hot Springs.		Lower Geyser Basin, Jug Spring.	Gibbon-Geyser Basin.			
	Cleopatra Spring.	Spring No. 17.		Echinus Geyser.	Pearl Geyser.	Opal Spring.	
	Grs. per imp. gall.[a]	*Grs. per imp. gall.*[a]	*Grs. per imp. gall.*[a]	*Grs. per imp. gall.*[a]	*Grs. per imp. gall.*[a]	*Grs. per imp. gall.*[a]	*Grains per gall.*
Sodium carbonate	....	17.92	50.75	....	....	....	....
Calcium carbonate	24.85	..	....	....	....	....	[b]100.00
Magnesium carbonate........	7.45	2.17	....	....	....	....	51.00
Sodium sulphate	35.50	34.37	....	11.59	1.89	....	117.00
Calcium sulphate.............	13.59	....	2.03	....	1.40	3.22	.....
Sodium chloride..............	13.50	18.90	31.57	13.65	61.39	82.18	270.00
Calcium chloride.............	....	....	....	....	....	4.06	....
Silica.........................	3.50	3.36	14.56	16.19	7.84	53.76	....
Sodium orthosilicate	....	....	....	10.58	....	....	....
Total..................	98.39	76.72	98.91	52.01	72.52	143.22	538.00

[a] Henry Leffmann, analyst (1882).

[b] With calcium sulphate.

UTAH.

The earlier explorers and travelers who crossed Utah on their way to the Pacific noted the presence of mineral waters and thermal springs, especially in the region of Great Salt Lake. These springs, some of them strongly saline, in many places furnish all the water to be obtained, except by long journeys. The thermal springs occur mainly in connection with faulted strata, and they also are generally saline and frequently sulphureted. Comparatively few are used as resorts, even locally, and none of the waters is known to be at present of commercial importance. The springs at Salt Lake City are probably the best known and most used for medicinal purposes. The "Utah Hot Springs," ten miles north of Ogden, formerly called "Red Springs" and "Bear River Springs," are used for bathing to a considerable extent. There is a hotel at the springs, and the place is utilized largely by residents of Ogden. "Beck's Hot Springs" are probably the springs 2 or 2½ miles north of Salt Lake City and the same as the springs analyzed by Jackson in 1850 and Gale in 1851. For a considerable number of localities and corrections of temperatures I am indebted to Mr. G. K. Gilbert.

Mineral springs of Utah.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Beck's Hot Springs, near Salt Lake City, Salt Lake County.	......	......	......	......	Bathing resort.
Blue Springs, 18 miles southeast of Snowville, Box Elder County.	6	......	86	Alkaline	Unimproved.
Carbonated Spring, 2 miles southwest of Draper, Salt Lake County.	1	......	Warm	Calcic, carbonated.	
Fish Springs, north end of Fish Spring Mountains, southwest of Granite Mountains, Juab County.	......	......	78	......	
Geyser (?) 25 miles south of Panguitch, Garfield County.	......	......	......	......	
Hot springs:					
In Juab County, 30 miles north of Deseret, Millard County.	20+	......	178	Saline, chalybeate.	Do.
Three miles west of Salt Marsh, Snake Valley, Millard County.	......	......	......	......	
Two and one-half miles north of Honeyville, Box Elder County.	5	......	132	Saline	Do.
Two and one-half miles north of city limits of Salt Lake City, Salt Lake County.	......	......	126	....do	Do.
Six or seven miles north of Utah Lake, in Utah County.	......	......	128	......	Probably same as spring near Draper.
Sixteen miles west of Minersville, Beaver County.	......	......	185	......	
In Spanish Fork Cañon, Wasatch Co.	......	......	145	......	
Hot Sulphur Springs, south end of Great Salt Lake Desert, near Fish Springs, Juab County.	9	......	139	Saline, chalybeate.	Unimproved.
Iron Springs, 8 or 9 miles northwest of Cedar City, Iron County.	12+	500+	......	Saline, chalybeate.	Do.
Jones's Warm Spring, ½ mile northwest of Salt Lake City, Salt Lake County.	1	......	93	Saline	

Mineral springs of Utah—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Knoll Springs, 20 miles north of Lake Creek, Millard County.			° 69	Sulphureted	
Locomotive Springs, near Seco, at north end of Great Salt Lake, Box Elder Co.					
Mineral springs:					
Fifteen miles southwest of Snowville, Box Elder County.					Unimportant.
In Tooele Valley, Tooele County					
Mound Springs, 3 miles above Plymouth, Box Elder County.	4	1,000	Hot		Local resort.
Salt Lake City Warm Spring, northwest part of Salt Lake City, Salt Lake Co.	1	32,903	103	Saline, sulphureted.	Used for bathing mainly.
Salt springs:					
At Monument Point, near end of Salt Lake, Box Elder County.					
In Hansell Spring Valley, Box Elder County.					
Eight miles west of Deweyville, Box Elder County.					
On Salina Creek, east of Salina, Sevier County.					
Sulphur springs:					
On Cliff Creek, south of Yampa Plateau, Uintah County.					
East side of Cedar Mountains, Tooele County.					
South end of Deep Creek Mountains, 28 miles southwest of Fish Spring, Juab County.					
In Iron County, thirty-three miles southwest of Minersville.					
Thermal spring, near Pah-Van Butte, in Sevier Desert.					
Undine Spring, Labyrinth Cañon, Emery County.					
Utah or Bear River Hot Springs, 8 or 10 miles north of Ogden City, Weber County.	12	6,500	132 to 136	Saline, chalybeate.	Bathing resort.
Virgin Hot Springs, near Virgin City, Washington County.					Local resort.
Warm and Hot Springs, near Midway, Wasatch County.	20	500+	116		Used locally by farmers.
Warm springs:					
At mouth of Ogden Cañon, Weber County.	2		150	Saline, calcic	
On west side of Stansbury Range, Tooele County.	1		74	Saline	
At north end of Stansbury Range, near Grantsville, Tooele County.	12		91	do	
At west base of Mineral Range, Beaver County.			74		
At head of Provo Cañon, Utah Co			72		
Near Cave Spring Settlement			90		
Near Cañon of Colorado			91		
At north end of Utah Lake, Utah Co.					
East side of Promontory Point, Box Elder County.	1		84		
Near Granite Mountain, Juab (?) Co.				Saline	
Three-fourths of mile south of Fish Springs, Juab County.	8		84½		
One and one-half miles south of Fish Springs, Juab County.	2		81		
On south edge of salt marsh in Snake Valley, Millard County.			67		
On west slope of Mineral Range, Beaver County.					
Warm sulphur springs:					
On north side of Ogden Cañon, Weber County.					

Analyses of mineral springs in Utah.

Constituents.	Carbonated Spring, near Draper.	Hot Spring, 2½ miles north of Salt Lake City.	Hot Spring, in region of Great Salt Lake.	Jones's Warm Spring.
	Parts in 1,000.[a]	*Parts in 1,000.*[b]	*Grains per gallon.*[c]	*Parts in 1,000.*[d]
Calcium carbonate	0.35	0.18	10.24	0.36
Magnesium carbonate	0.08			0.12
Magnesium sulphate	0.02			
Calcium sulphate		0.81		1.47
Potassium sulphate	0.10			
Sodium chloride	1.03	8.05		6.59
Calcium chloride		1.09		
Magnesium chloride		0.29		0.36
Potassium chloride	0.02			0.36
Manganese oxide			Trace	
Iron peroxide	0.01		1.67	Trace
Alumina				
Silica	0.05	0.18		0.02
Lime			23.26	
Chlorine			147.37	
Soda			122.75	
Magnesia			16.58	
Sulphuric acid			29.98	
Loss			0.15	
Total	1.66	10.60	352.00	9.28
Gases.				
Carbonic acid	In excess			Present
Sulphureted hydrogen				Present

Constituents.	Salt Lake City Warm Spring.			Utah or Bear River Hot Springs.	Warm Spring, near Granite Mountain.
	Grains per gallon.[c]	*Parts in 1,000.*[b]	*Parts in 1,000.*[d]	*Parts in 1,000.*[f]	*Parts in 1,000.*[g]
Calcium carbonate	3.58	0.75	0.33		
Magnesium carbonate		0.23	0.34	0.2016	
Sodium sulphate	5.52	0.65			
Calcium sulphate			1.37	0.3094	2.09
Iron chloride					0.02
Sodium chloride	19.54	8.17	7.72	18.0168	18.14
Calcium chloride	4.53	0.06		2.9187	0.58
Magnesium chloride	0.54		0.16	0.1398	0.97
Potassium chloride			0.34	1.6732	1.07
Iron peroxide	0.17		Trace		Trace
Alumina			Trace	0.0040	Trace
Silica			0.02	0.0460	
Nitric acid					Trace
Sulphureted hydrogen, absorbed.		0.87			
Total	33.88	10.23	10.28	23.3095	22.87
Gases.					
Carbonic acid			Present		Trace
Sulphureted hydrogen			Present		

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[a] I. T. Kingsbury, analyst (1882).
[b] L. D. Gale, analyst (1851).
[c] C. T. Jackson, analyst (1850).
[d] I. T. Kingsbury, analyst (1881).
[e] C. T. Jackson, analyst.
[f] F. W. Clarke, analyst (1884).
[g] I. T. Kingsbury, analyst (1884).

COLORADO.

Both hot and cold mineral springs abound in Colorado and contribute to the reputation of the State as a health resort. Considering the newness of the State, a fair proportion of its springs have been improved, and several of them have become known all over the country. Among these are Manitou Springs, at the base of Pike's Peak. The authorities for the list given here are the reports and maps of the Hayden Survey and of the Wheeler Survey and Dr. Charles Dennison's Rocky Mountain Health Resorts, supplemented by personal knowledge of a large number of the localities.

Mineral springs of Colorado.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Alkali Springs, near Monument Park, El Paso County.	......	....	......	....	
Alum Spring, in Schell Cañon, Purgatory River, Bent County.	......	....	......	....	
Antelope Springs, Antelope Springs, Hinsdale County.	......	....	......	....	
Agua Caliente, near Capulin, Conejos County.	......	....	......	....	
Artesian Well at Steel Works, Pueblo, Pueblo County.	1	....	......	....	Unimproved.
Artesian Magnetic Mineral Spring, near Union Depot, Pueblo, Pueblo County.	1	5,000	80	Sulpho-saline ...	Bathing resort.
Burdsall's Soda Lake Springs, Jefferson County.	......	....	......	....	
Cañon City Springs, Cañon City, Frémont County.	8	....	57	Carbonated	Resort.
Cañon City Hot Spring, 1 mile from Cañon City, Frémont County.	1	....	104	....	Do.
Cañon Creek Springs, near Ouray, Ouray County.	8	....	180 to 158	Sulphureted, &c.	
Carlisle Spring, near Beaver Creek, Pueblo County.	......	480	65	Saline	
Chalk Creek Hot Springs, near Heywood, Chaffee County.	12	....	150	Chalybeate, &c .	
Chalybeate Spring, in Spring Bottom of Arkansas River, Bent County.	......	....	......	....	
Cottonwood Hot Springs, Cottonwood Springs, Chaffee County.	......	....	......	....	
Elbert Iron Spring, near Rockwood, La Plata County.	1	....	90?	Chalybeate	Unimproved.
Estes Park Springs, Estes Park, Larimer County.	2	....	58	Saline, chalybeate.	Do.
Hartsel Hot Mineral Springs, Hartsel, Park County.	5	....	105	Sulphureted	Resort.
Hauman Hot Springs, east side San Luis Valley, Saguache County.	......	....	......	....	
Hot springs:					
On South Fork of Navajo River, southwest of Banded Peak, Conejos County.	......	....	80?	Sulphureted	
On Rock Creek, near Sopris Peak, Gunnison County.	12+	....	80 to 104	....	
Hot Sulphur Springs, Middle Park, Grand County.	22	16,980	91 to 117	Sulphureted	Do.
Idaho Hot Soda Springs, Idaho Springs, Clear Creek County.	....	2,000	85 to 120	Alkaline, saline .	Do.

Mineral springs of Colorado—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr. °	Character of the water.	Remarks.
Iron Lake Springs, near Silverton Pass, San Juan County.	......	....	......	Chalybeate	
Iron Springs, Bent County, northeast of Thatcher.	......	....	......	....do	
Iron Springs, 12 miles from Telluride, San Miguel County.	......	....	......	....	
Liberty Hot Springs, Wagon Wheel Gap, Rio Grande County.	8	....	140 to 150	Saline	Resort.
Manitou Springs, Manitou Springs, El Paso County.	9	895	48 to 60	Carbonated, saline, chalybeate.	Do.
Mineral springs:					
Mouth of cañon, on Purgatory River, Bent County.	......	....	......	....	Unimproved.
On Caddo Creek, 20 miles above mouth, Bent County.	......	....	......	....	Do.
Near Conejos, Conejos County.....	......	....	......	Thermal	
Four or five miles east of Cañon City, Frémont County.	......	....	......	....	
Three miles southeast of Pagosa Springs, Conejos County.	......	....	......	....	
One mile below Pagosa Springs, Conejos County.	......	....	6	....	Do.
On Cement Creek, near East River, Gunnison County.	......	....	......	Calcic	Do.
In Bidwell Basin, near Irwin, Gunnison County.	......	....	......	Sulphureted, chalybeate.	Do.
On White Earth River, Gunnison County.	5	....	48 to 84	Carbonated, calcic, and chalybeate.	Do.
Mineral Park Well (artesian), on Arkansas River, ½ mile above Pueblo, Pueblo County.	1	....	......	....	Used for bathing.
Morrison Spring, Morrison, Jefferson County.	1	....	......	Sulphureted	Resort.
Mound Soda Springs, Currant Creek, 9 miles from head, Park County.	8	....	......	Carbonated, alkaline.	Unimproved.
Ojos de los Caballos, San Luis Valley, Saguache County.	......	....	......	....	
Ouray Mineral Springs, Ouray, Ouray County.	9	....	120 to 140	Alkaline, carbonated, sulphureted.	
Pagosa Springs, Pagosa Springs, Conejos County.	4	....	148	....	Resort.
Parnassus Springs (or Red Creek Springs), Red Creek, near Beulah, Pueblo County.	5	....	59 to 71	Carbonated, saline, and sulphureted.	Has a local reputation.
Pinkerton Springs, 5 miles west of Trimble, La Plata County.	......	....	95	Alkaline.... ...	Unimproved.
Poncho Hot Springs, Poncho Springs, Chaffee County.	100+	1,000,000	90 to 168	....	Resort.
Porter's Spring, Denver, Arapahoe County.	......	....	60	Sulpho-chalybeate.	Improved.
Salt Creek Spring, Salt Creek, Pueblo County.	1	7,000	......	Saline	Used locally.
Salt springs:					
Between Fort Lyon and Kit Carson, Bent County.	......	....	......	....	
At Buffalo Springs, South Park, Park County.	......	....	......	....	
Seltzer Mineral Springs (formerly Peabody Springs), Springdale, Boulder County.[1]	8	1,000+	......	....	Resort and used commercially.
Shaw's Magnetic Springs, 5 miles from Del Norte, Rio Grande County.	......	....	......	....	Resort.

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[1] Walton describes these springs under the name "Rocky Mountain Springs," but the proprietor says he is at a loss to know the derivation of the name.

Mineral springs of Colorado—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Soda springs:			°		
Six miles south of Cañon City, Frémont County.					
East of Dillon, Summit County					
West of Leadville, Lake County					
On Pine Creek, south of Texas Creek, Frémont County.					
South Park Springs, south end of South Park, Park County.					
Steamboat Springs, Steamboat Springs, Routt County.	30			Saline, sulphureted.	Resort.
Stinking Springs, 2 miles from Salt Creek Springs, Pueblo County.					Unimproved.
Sulphur springs:					
Near head of Cement Creek, Gunnison County.					
East of Chicosa, Las Animas Co					
Three miles from Crested Butte, Gunnison County.					
On Grand River, near Gypsum, Eagle County.					
On Frying-Pan Creek, Pitkin Co					
Nineteen miles east of Huerfano, Huerfano County.					
Three miles west of Trinidad, Las Animas County.					
Tomichi Hot Springs, near Elgin, Gunnison County.	75		140 to 160	Saline, sulphureted.	Local resort.
Trimble Springs, Trimble, La Plata County.	2		130	Alkaline, saline.	Resort.
Tripp Springs, near Trimble, La Plata County.			95	Alkaline	Unimproved.
Uncompahgre Springs, Uncompahgre Park, Ouray County.					
Wellsville Warm Springs, Wellsville, Frémont County.					Do.

Analyses of mineral springs in Colorado.

Constituents.	Cañon City Springs.			
	Iron Duke.	Little Duke.	Big Ute.	Aqua Vida.
	Parts in 100.[a]	*Parts in* 100.[a]	*Parts in* 100.[a]	*Parts in* 100.[a]
Sodium carbonate	0.1267	0.1266	0.0594	0.1258
Calcium carbonate	0.0535	0.0374	0.0732	0.0678
Magnesium carbonate	0.0249	0.0234	0.0257	0.0302
Sodium sulphate	0.0201	0.0207	0.0280	0.0349
Sodium chloride	0.1372	0.1956	0.2258	0.2070
Total	0.3626	0.4040	0.4122	0.4558

[a] Oscar Loew, analyst (1875).

Analyses of mineral springs in Colorado—Continued.

Constituents.	Cañon City Springs.		Hot Spring, South Fork of Navajo River.	Rocky Mountain Springs.[a]
	Congress Spring.	Hot Spring.		
	Parts in 100.[b]	*Parts in* 100.[b]	*Parts in* 100,000.[b]	*Grains per gallon.*[c]
Sodium carbonate	0.0332	0.0119		3.79
Calcium carbonate	0.0482	0.0553	10.20	43.81
Magnesium carbonate	0.0300	0.0211	17.10	0.39
Iron carbonate				2.89
Sodium sulphate	0.0310	0.0134		104.60
Calcium sulphate			61.50	
Sodium silicate				4.00
Sodium chloride	0.0652	0.0301		4.96
Sodium iodide Sodium bromide				1.30
Total	0.2063	0.1320	88.80	165.24

Constituents.	Hot Sulphur Springs, Middle Park.			
	Spring No. 1.	Spring No. 2.	Spring No. 3.	Spring No. 4.
	Grains per gallon.[d]	*Grains per gallon.*[d]	*Grains per gallon.*[d]	*Grains per gallon.*[d]
Sodium carbonate	58.57	50.45	20.37	29.42
Calcium carbonate	10.08			8.46
Magnesium carbonate	6.57	4.14		2.66
Sodium sulphate	8.48	8.97	17.58	14.25
Potassium sulphate	0.50	0.07	1.03	7.03
Magnesium sulphate			5.26	
Sodium silicate		1.46		
Sodium chloride	14.61		13.29	12.18
Silica			0.61	0.54
Magnesia		Trace		
Lithia	Trace	Trace	Trace	
Iron	Trace	Trace	Trace	Trace
Ammonia			Trace	Trace
Carbonic acid (free)	2.94		8.42	0.42
Total	101.75	65.09	66.51	74.96

Constituents.	Hot Sulphur Springs, Middle Park.		Estes Park Springs.	
	Spring No. 5.	Spring No. 6.	River Spring.	Ranch Spring.
	Grains per gallon.[d]	*Grains per gallon.*[d]	*Parts in* 100,000[e]	*Parts in* 100,000.[e]
Sodium carbonate	39.37	22.42		
Calcium carbonate	3.68	6.43	2.84	6.89
Magnesium carbonate	1.93		2.01	1.83
Iron carbonate			6.66	3.12
Sodium sulphate	9.85	25.11		
Potassium sulphate	0.96	1.69	0.99	1.09
Sodium chloride	13.97	13.11	1.31	1.82
Silica	1.31	1.36	0.78	0.99
Alumina			Trace	Trace
Iron	Trace	Trace		
Ammonia	Trace	Trace		
Organic matter			1.79	2.06
Carbonic acid (free)	9.49	4.69		
Total	80.56	74.81	16.38	17.80

[a] Probably Seltzer Springs.
[b] Oscar Loew, analyst (1875).
[c] C. T. Jackson, analyst.
[d] E. J. Mallet, jr., analyst (1875).
[e] C. F. Chandler, analyst.

Analyses of mineral springs in Colorado—Continued.

Constituents.	Idaho Hot Soda Springs.	Seltzer Mineral Springs.	Porter's Spring.	Hartsel Hot Mineral Springs.	Carlisle Spring.	Chalk Creek Hot Springs.
	Parts in 100,000.[a]	*Parts in* 100,000.[b]	*Parts in* 100,000.[c]	*Parts in* 100,000.[d]	*Parts in* 100,000.[c]	*Parts in* 100,000.[d]
Sodium carbonate	52.81	9.87	9.97	130.55	15.42	....
Potassium carbonate	....	....	....	....	....	0.23
Calcium carbonate	16.32	74.29	17.63	19.89	38.40	3.35
Magnesium carbonate	4.94	1.14	1.71	11.09	19.52	1.08
Iron carbonate	7.07	6.86	2.57	....	0.51	....
Sodium sulphate	50.34	184.46	47.23	9.69	34.28	10.58
Potassium sulphate	....	....	0.52	....	1.20	....
Magnesium sulphate	32.09	....	....	....	....	....
Sodium silicate	6.99	6.86	1.54	....	....	4.45
Sodium sulphide	....	....	3.27	....	....	....
Sodium chloride	7.13	8.51	9.14	165.08	19.30	....
Potassium chloride	....	....	....	32.58	....	1.00
Magnesium chloride	....	....	1.96	....	....	....
Sodium iodide }	....	2.23	....	....	....	....
Sodium bromide }			....	....	....	....
Silica	....	....	....	0.92	Trace	3.49
Lithia	....	....	....	....	....	Trace
Alumina	....	....	....	0.65	....	....
Ammonia	....	....	Trace	....	....	....
Organic matter	....	....	....	....	Trace	Trace
Sulphur	....	....	....	Present	....	....
Total	177.69	298.72	95.54	370.40	128.63	24.27

Constituents.	Manitou Springs.					
	Iron Ute Spring.	Little Chief Spring.	Manitou Spring.	Navajo Spring.	Ute Soda Spring.	Shoshone Spring.
	Parts in 100,000.[e]	*Parts in* 100,000.[e]	*Parts in* 100,000[e]	*Parts in* 100.000.[e]	*Parts in* 100,000.[e]	*Parts in* 100,000.[e]
Sodium carbonate	59.34	15.16	52.26	124.69	23.82	88.83
Calcium carbonate	59.04	75.20	111.00	129.40	40.00	} 108.50
Magnesium carbonate	14.56	13.01	20.51	31.66	6.10	}
Lithium carbonate	Trace	Trace	0.21	0.24	Trace	Trace
Iron carbonate	5.78	1.80	Trace	......	1.40	....
Sodium sulphate	30.86	51.88	19.71	18.42	12.24	37.05
Potassium sulphate	7.01	6.24	13.85	16.21	Trace	5.12
Sodium chloride	31.59	47.97	40.95	39.78	13.93	42.12
Silica	2.69	2.22	2.01	1.47	Trace	Trace
Total	210.87	213.48	260.00	361.87	97.49	281.62

[a] I. G. Pohle, analyst.
[b] C. T. Jackson, analyst (1877).
[c] E. J. Mallet, jr., analyst.
[d] George E. Patrick, analyst.
[e] Oscar Loew, analyst (1875).

Analyses of mineral springs in Colorado—Continued.

Constituents.	Liberty Hot Springs.			Parnassus Springs.		
	Spring No. 1.	Spring No. 2.	Spring No. 3.	Spring No. 1.	Spring No. 2.	Spring No. 5.
	Parts in 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]
Sodium carbonate	69.42	Trace	144.50	126.04	118.45	73.32
Calcium carbonate	13.08	31.00	22.42	71.00	54.54	46.91
Magnesium carbonate	10.91	5.10			22.43	17.03
Lithium carbonate	Trace	Trace	Trace	Trace	1.78	0.15
Iron carbonate	....	....	....	1.54	2.23	2.75
Sodium sulphate	23.73	10.50	13.76	8.78	3.98	3.28
Potassium sulphate	Trace	Trace	Trace	19.22	18.44	14.54
Sodium chloride	29.25	11.72	33.84	102.96	104.13	53.23
Silica	5.73	1.07	4.75	4.21	7.94	6.00
Organic matter	Trace	Trace	Trace	Trace	Trace	....
Sulphureted hydrogen	Trace	12.00	....	....	....	Trace
Carbonic acid	....	....	....	In excess	In excess	In excess
Total	152.12	71.39	218.77	333.75	333.92	217.21

Constituents.	Pagosa Springs.			
	Spring No. 1.	Spring No. 2.	Spring No. 3.	Spring No. 4.
	Parts in 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]
Sodium carbonate	4.70	3.33	....	....
Calcium carbonate	59.00	59.50	54.51	58.73
Magnesium carbonate	4.85	3.92	3.68	3.59
Lithium carbonate	0.71	Trace	Trace	Trace
Sodium sulphate	221.66	220.20	223.92	224.59
Potassium sulphate	7.13	6.98	6.63	7.10
Sodium chloride	29.25	29.36	31.21	29.81
Silica	5.70	5.21	5.53	3.82
Organic matter	Trace	Trace	Trace	Trace
Total	333.00	328.50	325.48	327.64

[a] Oscar Loew, analyst (1875).

NEW MEXICO.

In many portions of New Mexico, alkaline and saline waters (many of them warm or hot) are doubtless more prevalent than are pure waters. The mineral springs that are utilized for medicinal purposes are numerous, and some of them were used years ago by the Franciscan and Dominican friars, and by the Indians prior to the advent of Europeans. Many of the hot springs have widespread reputations throughout the Southwest. Among those most used at the present time are Las Vegas, Jemes, Joseph's Ojo Caliente, and Hudson's Hot Springs. The present list for the Territory is compiled mainly from information furnished by members of the United States Geological Survey whose field of work has been in New Mexico. Various Government exploration and geological reports and hand-books have also been drawn upon. The analyses, with one exception, have been taken from the Report of the United States Geographical Survey West of the 100th Meridian (Vol. III, Geology).

Mineral springs of New Mexico.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Apache Tejo Warm Springs, south of Fort Bayard, Grant County.			89°		
Agua Caliente, near Mesilla (?), Dona Ana County.					
Aztec Spring (Ojo Xigante), 4 miles east of Santa Fé, Santa Fé County.					Water is on sale in Santa Fé.
Caballo Springs (?), 5 miles from Fort McRae, Socorro County.			136		
Geyser in Bernalillo County, 12 miles northeast of Fort Wingate.			Warm		
Hudson's Hot Springs, near Hudson, 4 miles northwest of Mimbres, Grant County.					Resort.
Hot springs:					
In San Diego Cañon, on San Antonio Creek, north of Jemes, Bernalillo County.					
Near the Rio Grande, north of Palomas, Socorro County.					
On Diamond Creek, near mouth, Socorro County.			151		
Gila River, near Diamond Creek, Socorro County.			100		
Jemes Hot Springs (lower group), twelve miles above Jemes, Bernalillo County.	10+		94 to 168	Saline	Do.
Jemes Hot Springs (upper group), San Diego Cañon, 14 miles above Jemes, Bernalillo County.	40		70 to 105	do	Do.
Las Vegas Mineral and Hot Springs, near Las Vegas, San Miguel County.	40		75 to 140	Alkaline, saline.	Do.
Mineral springs:					
Three miles east of Gallup, Bernalillo County.					
Eighteen miles west of Abiquiu, Rio Arriba County.					
Five miles east of Ojo Azufre, Bernalillo County.				Alkaline	
East of Great Ranch and 8 miles northeast of Las Vegas, San Miguel County.				Alkaline, sulphureted.	
Ojo Azufre, Bernalillo County, 20 miles west of Fort Wingate.				Sulphureted, &c.	
Ojo Caliente (Joseph's), Taos County, 12 miles from Barranca, north of Abiquiu.	4+	6,000	108 to 122	Alkaline and saline, thermal.	Used commercially and as a resort.
Ojo Caliente, Mimbres River, 15 miles north of Mimbres, Grant County.					
Ojo Caliente, 12 miles southwest of Zuñi, Valencia County.					
Ojo Caliente, near Cherryville and Canada Alamosa, Socorro Co.			85		
Ojo Sarco, on Rio Grande north of Santa Barbara, Taos County.					
San Ysidro Spring, near Jemes, Bernalillo County.				Carbonated	
Soda springs:					
Three miles north of Ojo Caliente, Taos County.					
On Salado Creek, 4 or 5 miles south of San Ysidro, Bernalillo County.					
Four or 5 miles south of Carrigo Valley, Socorro County.					
Thirteen miles northeast of Isleta, Bernalillo County.					
Stinking Spring, 10 miles northeast of Coolidge, Valencia Co.				Sulphureted	

Mineral springs of New Mexico—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Sulphur springs:			°		
In Chusca Valley, Rio Arriba County.	......	....	....	....	
West of Mesa Lucera, Valencia County.	......	....	....	....	
Five miles south of Taos, Taos County.	......	....	....	....	
Warm springs:					
Near Hudson, 6 miles northwest of Mimbres, Grant Co.	......	....	150	....	
At head of San Diego Cañon, Rio Arriba County.	......	....	....	....	
At copper mines of Rio San Francisco, Socorro Co.	......	....	130	....	
Warm Sulphur Spring, Rio Pajarito, Taos County.	......	....	68	....	

Analyses of mineral springs in New Mexico.

Constituents.	Ojo Caliente (Joseph's).		Jemes Hot Springs.			Las Vegas Mineral and Hot Spring.
	Spring No. 1.	Spring No. 2.	Geyser.	Spring No. 3.	Spring in upper group.	
	Parts in 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100.[a]	*Parts in* 100.[a]	*Parts in* 100.[a]	*Parts in* 100,000.[a]
Sodium carbonate	196.95	184.29	....	....	0.0219	120.00
Calcium carbonate	6.25	5.40	0.0641	0.0300	0.0548	13.75
Magnesium carbonate			0.0103	0.0240	0.0057	
Lithium carbonate	0.21	0.16	....	....	....	....
Iron carbonate	Trace	Trace	....	0.0002	....	....
Sodium sulphate	13.60	19.33	0.0035	....	0.0059	5.26
Potassium sulphate	5.17	5.34	....	....	....	....
Calcium sulphate	....	....	Trace	0.0262	....	....
Sodium chloride	38.03	39.78	0.1622	0.1508	0.2642	6.41
Silica	Trace	Trace	Trace	0.0010	0.0201	Trace
Potassa	....	....	Trace	Trace	Trace	....
Lithia	....	....	Trace	Trace	Trace	....
Phosphoric acid	....	....	....	....	Trace	....
Total	260.21	254.30	0.2401	0.2322	0.3726	[b]145.42

Constituents.	San Ysidro Spring.	Warm Sulphur Spring, Rio Pajarito.	Las Vegas Mineral and Hot Springs.			Aztec Spring.
			Spring No. 1.	Spring No. 2.	Spring No. 3.	
	Parts in 100.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[b]
Sodium carbonate	....	17.01	1.72	1.17	5.00	....
Calcium carbonate	0.0670	7.19	9.08	10.63	11.41	0.1538
Magnesium carbonate	0.0248					0.0605
Iron carbonate	0.0008	....	....	....	....	....
Sodium sulphate	0.1639	14.60	14.12	15.93	16.27	0.0225
Calcium sulphate	....	....	....	....	....	0.0050
Sodium chloride	0.3072	9.11	27.26	24.37	27.34	0.0193
Silica	Trace	Trace	1.04	Trace	2.51	0.0220
Potassa	Trace	Trace	Trace	Trace	Trace	....
Lithia	Trace	Trace	Strong trace	Strong trace	Strong trace	....
Total	0.5632	47.91[c]	53.22	52.10	62.53	0.2831

[a] Oscar Loew, analyst (1875).
[b] F. W. Clarke, analyst (1885).
[c] Contains carbonic acid and hydrogen sulphide also.

ARIZONA.

Definite information relating to the mineral springs of Arizona is difficult to obtain, and the list given here is not offered as complete. In some portions of the Territory alkaline, saline, and sulphureted waters are so numerous that they attract but little attention. So far as can be ascertained, none of the springs included in the table has been improved, although the Monroe Springs are said to have been used to some extent for bathing. Saline springs appear to be most abundant and a large number of them are thermal. Many of them will probably be utilized for medicinal purposes as the country becomes more thickly populated. The few analyses given have been derived from Vol. III (geology) of Wheeler's survey reports.

Mineral springs of Arizona.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.
			°	
Alkali springs, in Boo-koo-der-klish Cañon, Apache County				Saline, alkaline.
Agua Caliente, opposite Burke's Station, on Gila River, Maricopa County.				Saline.
Agua Sal Creek, southwest of Carriso Mountain, Apache County				
Bitter Spring, south of Lee's Ferry, on Colorado River, Yavapai County.				
Croton Springs, in Sulphur Springs Valley, Cochise County	2			Do.
Gypsum Spring, in Detrital Valley, Mohave County				
Hos-hi-ti-to Spring, southwest of Carriso Mountain, Apache County				Do.
Hot springs:				
Opposite mouth of Cabicu Creek, Gila County				
East of Black Cañon of Colorado River, Mohave County				
On Rio San Francisco, 7 miles above the mouth, Graham County	4		127–130	Do.
Lava springs, in Grand Cañon of Colorado River, Mohave County			89	
Mineral springs, 13 miles northwest of Green's Peak, Apache County				
Mineral Park Bitter Spring, in Cerbat Range, Mohave County				
Monroe Hot Spring, Castle Creek, 60 miles south of Prescott, Maricopa County. (Bathing resort.)	1	4,200	150–160	
Not-tahn-de-let Spring, 20 miles north of Keam's Cañon, Apache County.				Alkaline, saline.
Pahgun Spring, in Grand Wash of Colorado, Mohave County			100	
Salt springs:				
Along cañon of Salt River, Gila County				
South of Stone's Ferry, on Colorado River, Mohave County				
Fifty or 60 miles northeast of Williams's Trading Post, Apache Co				
On the Colorado Chiquito, near Hardy, Apache County				
Sand Cave Spring, Apache County, 50 miles northwest of Fort Defiance.				Sulphureted.
Shanto Spring, 40 miles northwest of Fort Defiance			Tepid.	
Shanto Spring, 50 miles northwest of Williams's Trading Post, Apache County.			do	Alkaline.
Sulphur Spring, southwest of Camp Bowie, Cochise County				
Thermal springs:				
Near Tubac, Pima County				
On Prieto River, Graham County				

Analyses of mineral springs in Arizona.

Constituents.	Mineral Park, Bitter Spring.	Gypsum Spring, Detrital Valley.	Hot Springs, Rio San Francisco.
	Parts in 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100.[a]
Magnesium carbonate	....	Trace	....
Calcium carbonate	....	12.0	....
Sodium sulphate	Trace	51.6	....
Magnesium sulphate	65.3	172.8	....
Calcium sulphate	118.5	130.1	0.0410
Iron sulphate	Trace	....	....
Manganese sulphate	Trace	....	....
Sodium chloride	....	397.8	0.3252
Potassium chloride	....	Trace	....
Magnesium chloride	5.4	....	0.1025
Calcium chloride	....	....	0.1981
Total	189.2	764.3	0.6668

[a] Oscar Loew, analyst (1875).

NEVADA.

The State of Nevada is better off in respect to springs than in regard to streams of running water. She occupies a prominent place as a mineral-spring State. Both hot and cold springs (the former predominating) are found in every county. Walton's work credits the State with two localities, and yet there are at least ten localities that are utilized for medicinal purposes, and many of them were so used by the Indians long before settlements were made by the whites. Our table includes more than one hundred localities, and yet only a part of the actual number of springs are given, for some of the groups contain as many as forty or fifty or even more individual springs. It is impossible at present to give the total number of springs. Steamboat Springs is probably the best known resort, as it has long been readily accessible. The warm and hot springs are found mainly in connection with geological fault-lines or fractures of the strata. Salt springs and borax springs are numerous. Sulphureted springs are frequently found also. So few of the springs have been analyzed that the greater part of them must be considered as unknown, so far as their chemical character is concerned. The list of springs has been compiled from various maps and such Government reports as were accessible, supplemented by information furnished by members of the United States Geological Survey who have worked in Nevada.

Mr. I. C. Russell and Dr. W. J. Hoffman have added largely to the list from their personal knowledge of the State, and thanks are also due to Mr. L. A. Buckner, of Winnemucca, Nev.

Mineral springs of Nevada.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Alkali springs:			°		
Seven miles north of Montezuma, Esmeralda County.	......	......	......	......	
Ten miles northwest of Lone Mountain, Esmeralda County.	......	......	......	......	
Allen's Spring, south of Carson's Lake, Churchill County.	......	......	......	......	
Alum Spring, 5 miles northeast of Steamboat Springs, Washoe County.	......	......	......	......	
Bitter Springs, 15 miles southwest of Saint Thomas, Lincoln County.	......	......	......	......	
Butte Spring, north end of Hot Springs Butte, Humboldt County.	......	......	182	......	
Double Spring, north of Walker Lake, Esmeralda County.	......	......	Warm.	......	
Double Hot Springs, southwest flank of Black Rock Range, Humboldt County.	......	......	191–165	......	
Elko Hot Springs, Elko, Elko County.	......	......	......	......	Resort.
Franktown Hot Springs, Franktown, Washoe County.	......	......	......	......	
Goloonda Hot Springs, Goloonda, Humboldt County.	6	......	150	Chalybeate and sulphur.	Do.
Goodrich Spring, 12 miles from Schellbourne, White Pine County.	......	28,000	160–185	......	Unimproved.
Granite Creek Hot Spring, near Alkali Lake, north of Granite Creek Desert, Humboldt County.	......	......	......	......	
Gypsum Spring, 20 miles northeast of Las Vegas, Lincoln County.	......	......	......	......	
Hot springs:					
On north side of Thousand Creek Valley, southwest of Stein Mountains, Humboldt County.	......	......	130	......	Do.
In Soldier Meadows, 15 miles south of Camp McGarry, Humboldt County.	......	......	......	......	
At south end of Stein Mountains, Humboldt County.	......	......	178	......	
Ten or 12 miles north of Mason's Crossing of Quinn River, Humboldt County.	2	......	118–134	Calcic?	
On east side of Independence Valley, Elko County.	......	......	......	......	
At northeast end of Ruby Lake, Elko County.	......	......	......	......	
East of Division Peak and south of Pah Ute, Humboldt County.	......	......	......	......	
On northeast side of Pine Valley, north of Mineral Hill, Eureka County.	......	......	......	......	
South of Alkali Lake, east side of Crescent Valley, Eureka County.	......	......	......	......	
On northeast side of Pah Ute Mountains, Churchill County.	......	......	......	......	
In Antelope Valley, near Eagle Lake, Elko County.	......	......	......	......	
Northwest of Sink of Quinn River, Humboldt County.	2	......	......	......	
Near Egan Cañon, 15 miles northwest of Schellbourne, White Pine County.	......	......	......	......	Used for quartz mill and for bathing.
At northwest end of Pyramid Lake, Washoe County.	......	......	......	......	
At north end of Pyramid Lake, Washoe County.	......	......	......	......	
On Carson River, 6 miles northeast of Genoa, Douglas County.	......	......	......	......	
At south end of Smoke Creek Desert, Washoe County.	......	......	......	......	
At north end of Toquima Range, 18 miles southeast of Austin, Lander County.	......	......	......	......	

Mineral springs of Nevada—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Hot springs—Continued.			°		
Near junction of Beef and Virgin Creeks, Humboldt County.	......	......	108	....	
On Little Humboldt, north of Hot Spring Creek, Humboldt County.	......	......	180	....	
In Kobeh Valley, near Grubb's Mill, Eureka County.	......	......	......	....	
On west side of Smith Creek Valley, Churchill County.	......	......	......	....	
On west side of Gabb's Valley, Esmeralda County.	......	......	......	....	
One mile east of Carson City, Ormsby County.	......	......	111	....	Improved.
Ten miles north of Wellington, Lyon County.	.....	91,000	40–140	....	Resort.
East of Hot Springs Station, Churchill County.	6	......	158–187	....	
East of Winnemucca, Humboldt County.	......	......	189	....	
At head of north branch of Little Humboldt, Humboldt County.	......	......	......	....	
At head of south branch of Little Humboldt, Humboldt County.	......	......	......	....	
On southwest side of Black Rock Range, Humboldt County.	3	......	......	....	
At south end of Black Rock Range, Humbolt County.	......	......	......	....	
Near south end of Pine Forest Range, 7 miles from Mason's Crossing of Quinn River, Humboldt County.	......	......	155	....	
In Emigrant Cañon, northeast of Tulasco, Elko County.	......	......	......	....	
At south end of Thousand Springs Valley, Elko County.	......	......	......	....	
At Cephas Kyles, 7 miles south of Sue Springs, Churchill County.	......	......	125	....	
At base of Shoshone Range, Reese River Valley, Lander County.	....	......	85–117	....	
In Steptoe Valley, southwest of Ruby Valley, White Pine County.	......	......	......	....	
Near Silver Peak, Esmeralda County.	11	......	69–117.8	Saline, &c	
Fourteen miles south of Toyabe City, Nye County.	1	35,000	Boiling	....	
In Diamond Valley, 30 miles north of Eureka, Eureka County.	......	......	......	....	
In Hot Spring Range, Nye County.	2	......	Boiling	....	
In Salt Valley, east side of Carson Sink Mountains, Churchill Co.	......	......	......	....	
Hot Sulphur Springs, Carlin, Elko Co	......	......	......	....	
Kyle's Hot Springs, 12 or 15 miles east of Star Peak, Humboldt County.	......	......	......	....	Do.
Las Vegas Springs, Las Vegas, Lincoln County.	.....	......	73	Calcic?	
Leach's Hot Springs, Pleasant Valley, 25 miles south of Winnemucca, Humboldt County.	......	......	118	....	
Mesquit Springs, 10 miles east of Las Vegas Lincoln County.	....	......	......	....	
Miller's Hot Springs, 10 miles north of Franklin, Ruby Valley, Elko County	......	......	170	....	
Mineral Hill Hot White Sulphur Springs (Bruffy's Hot Springs), 4 miles north of Mineral Hill, Eureka County.	5	150+	Boiling	Sulphureted	Do.
Mineral springs:					
Opposite Stonehouse Station, Humboldt County.	......	......	......	....	
West side of Smoke Creek Desert, Washoe County.	......	......	......	....	

Mineral springs of Nevada—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Muddy Springs, northwest of West Point, Lincoln County.	20+		Hot		
Mud Springs, Desert Wells, Nye Co					
Nelson Springs, 20 miles south of Golconda, Humboldt County.			Hot		
Red Bluff Springs, 10 miles east of Saint Thomas, Lincoln County.				Alkaline; saline.	
Rotten Egg Springs, west side of Mud Lake, Washoe County.					
Salt Well, 1 mile north of Stone's Ferry, Lincoln County.			89.5	Saline	
Schellbourne Hot Springs, Schellbourne, White Pine County.	2				Used for irrigation.
Shaw's Hot Springs (formerly Swift's), two miles northeast of Carson City, Ormsby County.	1	4,000	120	Saline	Resort.
Hot water of Ophir Mine, Comstock Lode, Virginia City, Storey County.					
Smoky Valley Geysers, Nye County		4,200+	Boiling		
Soda Lakes, 3 or 4 miles east of Ragtown, Churchill County.				Alkaline; saline.	
Soda springs:					
East of South Carson Lake, Churchill County.			178		
South of Silver Peak, Esmeralda County.					
Near Butlerfield's, Warm Springs, west of Railroad Valley, Nye Co				Saline, &c	
Steamboat Springs, Steamboat, Washoe County.			204		Do.
Sue (or Gilbert's) Hot Springs, north end of Osobb or Salt Valley, Humboldt County.			160-185		
Sulphur springs:					
In Esmeralda County, 12 miles southeast of Wellington.					
In Sodaville, Soda Springs Valley, north of Columbus, Esmeralda County.					Improved and used as a resort
At south end of Diamond Valley, Eureka County.					
Seven miles east of Montezuma, Esmeralda County.					
Eight or 9 miles northeast of Toyabe City, Nye County.					
Twenty miles south of Freyberg, Lincoln County.					
In Pahrimp Valley, Lincoln Co					
At Sand Spring Flat, 15 miles south of Stillwater, Churchill County.			Hot		
Thermal springs:					
On east side of Little Cedar Mountains, Elko County.					
At east base of Keene Mountains, San Antonio, Nye County.	3			Alkaline	
Five miles east of Patterson, Lincoln County.					
Virgin River, Lincoln County				Strongly saline	
Volcanic Springs, Whirlwind Valley, Lander County, 10 miles south of Beowawe.					
Wabuska Springs, Wabuska, Lyon County.			138-162		
Walley's or Genoa Hot Springs, Genoa, Douglas County.	6	600	Hot		Resort.
Ward's Hot Springs, foot of Granite Mountains, Humboldt County.			Boiling		
Warm springs:					
Northwest of Shoshone Mesa, west of Rock Creek, Lander County.					

Mineral springs of Nevada—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Warm springs—Continued.			°		
On White River, in Sierra Valley, 20 miles northeast of Butterfield, Nye County.	....	....	....	....	
South of Sonoma Range, Humboldt County.	......	....	....	....	
On west side of King River Valley, Humboldt County.	2	....	76-80	....	
Eight miles southwest of Camp Halleck, Elko County.	......	....	....	....	
At Hiko, Lincoln County	......	....	90	....	
In Pahrimp Valley, Lincoln County	......	....	....	....	
West of Roberts Mountains, Eureka County.	......	....	....	....	
Northwest of Tecoma, Elko Co...	......	....	....	....	
South of Alkali Lake, Reese River Valley, Lander County.	......	....	....	....	
On west side of Warm Spring Valley, Nye County.	......	....	....	....	
At north end of Grass Valley, Lander County.	......	....	....	....	
In Storey County, 10 or 12 miles south of Wadsworth.	......	....	73	....	
At north end of Carico Valley, Lander County.	......	....	....	....	
At east side of Sonoma Mountains, Humboldt County.	......	....	....	....	
In Fish Spring Valley, southeast of Danville, Nye County.	......	....	....	....	
Six miles north of Hot Springs, Smith's Creek Valley, Churchill County.	......	....	....	....	
In Ash Meadows, Nye County	......	....	81.6	....	
At north end of White Pine Valley, White Pine County.	......	....	....	....	
West of Fish Creek Range, Lander County.	......	....	140	....	
Warm Sulphur Springs, south end of Spring Valley, White Pine County.	......	....	....	....	
Whelan's White Sulphur and Mineral Springs, Pine Valley, 12 miles north of Mineral Hill, Eureka County.	3	5,000	108-112	....	Local resort.

Analyses of mineral springs in Nevada.

Constituents.	Larger Soda Lake, near Ragtown.			Ward's Hot Springs, Granite Mountain.	Hot Springs at Hot Spring Station.	Hot water from Ophir Mine.
	Surface water.	30½ inches below surface.	Unspecified.			
	Grams per liter.[a]	*Grams per liter.*[a]	*Parts in 1,000.*[b]	*Grams per liter.*[a]	*Grams per liter.*[a]	*Grains per gallon.*[c]
Sodium carbonate	26.410	24.840	29.25			
Magnesium carbonate	0.940	0.940	0.06			2.82
Calcium carbonate						4.10
Sodium sulphate	19.170	19.450	13.76	0.4267	0.4039	2.67
Magnesium sulphate				0.0179	0.0050	2.93
Calcium sulphate				0.1247	0.1037	10.01
Aluminium sulphate					0.0063	
Potassium sulphate			3.65			0.65
Sodium chloride	71.470	68.930	64.94	0.3665	1.4946	0.60
Potassium chloride	4.820	5.110		0.0363	0.1278	
Sodium biborate	0.404	0.417				
Sodium sulphide			0.24			
Sodium silicate				0.1942	0.1480	
Silica	0.304	0.310	0.21			2.21
Silica free				0.0180	0.2060	
Carbonic acid in excess.			0.47			
Loss	1.612	5.153	2.12	0.0059		0.27
Alumina						Trace
Total	125.130	125.150	114.70	1.1902	2.4953	26.25

[a] T. M. Chatard, analyst (1884). [b] O. D Allen, analyst (1877). [c] George Atwood, analyst.

CALIFORNIA.

The States of the Pacific coast are remarkable for the number of their mineral springs, especially of hot and warm springs, and California stands at the head of the list, having probably more localities than any other State, east or west. Our table does not give the total number of individual springs, since complete reports have been received from comparatively few of the localities included. The springs are classified as sulphureted, carbonated, alkaline, saline, chalybeate, and acid. Naturally many of the springs are thermal, for the volcanic rocks with which such springs are usually associated are found in many portions of the State. A large number of the California springs are improved and utilized as places of resort, being visited by thousands of people annually. Many, however, are comparatively inaccessible, and are therefore little known. The best known springs are probably the Geyser Springs of Sonoma County, which are really a collection of fumaroles, solfataras, and boiling springs. There are nearly a dozen localities at which the waters are put up for sale and shipment.

The list of springs given here has been compiled from various sources. The report of Dr. F. W. Hatch, in the Sixth Report of the State Board of Health, for 1880, and various hand-books (among them Truman's Illustrated Guide and U. H. Chittenden's Health and Pleasure Resorts of the Pacific Coast) have been drawn upon in its preparation. Besides these, the reports of the State mineralogist, Henry G. Hanks, Whitney's geological reports, and the various Government geological publications have been consulted, and all this has been supplemented by reference to the various maps of the State. For the northern portion of the State many additional data, that have never been published, have been obtained from Mr. Gilbert Thompson, Mr. Mark B. Kerr, and Mr. Eugene Ricksecker, of the United States Geological Survey, who have worked in that section of the State recently. Dr. W. J. Hoffman and Mr. I. C. Russell have kindly given information as to other parts of the State.

Mineral springs of California.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Adams Spring, 2 miles from Cobb's Valley, 8 miles south of Clear Lake, Lake County.	1			Alkaline, carbonated.	Resort.
Ætna Springs, 16 miles northeast from Saint Helena, Napa County.	2+	98–106		do	Do.
Alkali springs:					
In north end of Mono County.					
Eight miles northwest of Quincy, Plumas County.				Alkaline, carbonated.	
One mile above mouth of Spanish Creek, Plumas County.				do	
Alkaline lakes:					
Fifteen miles southwest of Alturas, Modoc County.					
Near Clear Lake, Lake County.					
Alabaster Cave Spring, El Dorado Co.					
Alameda Warm Springs, Alameda Co., near San José.					
Allen Springs, near head of Cache Creek, Allen Springs, Lake Co.	5		50 ?	Alkaline, saline, and chalybeate.	Do.
Alum Rock Springs, 7 miles northeast of San José, Santa Clara County.	4+		85	Saline, sulphureted.	
Anderson's Springs, Lake County, 19 miles north of Calistoga.	9				Resort to limited extent.
Agua Caliente, in Coahuila or Cabeson Valley, 10 miles south of White River, San Diego County.			100.4		
Agua Caliente, 30 miles from Caliente Station, Kern County.			80	Thermal	
Arrowhead Hot Springs,? near San Bernardino, San Bernardino County.		140–210			Probably same as San Bernardino.
Azule Mineral Springs, 12 miles west of San José, Santa Clara County.	3	250			Used commercially.
Bartlett Springs, near head of Cache Creek, Bartlett Springs, Lake County.	2+		Cold	Alkaline, saline	Used commercially and as a resort.
Bear Valley Hot Springs, near Bear Lake, north of San Bernardino Peak, San Bernardino County.					
Berkeley or Summit Soda Springs, 10 miles south of Summit Station, on Central Pacific Railroad, Placer Co. ?				Alkaline	Possibly same as Summit Soda Springs.
Bitter Spring, 18 miles north of Camp Cody, San Bernardino County.					
Black Lake, 1 mile west of Benton, Mono County.				Alkaline	
Blanck's (Mrs. Lottie) Hot Sulphur Spring, Colusa County.					
Boiling Lake, 7 miles south of Lassen's Peak, Plumas County.					
Boiling Springs, east side of Dry Salt Lake, west side of Resting Mountains, Inyo County.					

Mineral springs of California—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Boiling Sulphur Springs, northwest of Long Valley, South Branch of Owen's River, Mono County.					
Bonanza Springs, 1½ miles from Howard Springs, Lake County.	3			Sulphureted, chalybeate.	Resort.
Borax Flat Springs, near intersection of 117° 15′ and 35° 45′, San Bernardino Co.					
Borax Marsh Springs, 8 miles southeast of Hawley's Station, San Bernardino County.					
Borax Patch Springs, near Black Ranch, near Central Pacific Railroad, San Bernardino County.					
Boyd's Hot Springs, Surprise Valley, on east side of Upper Alkali Lake, Modoc County.					
Branbeck's Springs, east side of Honey Lake, Lassen County.			Boiling		
Byron Spring, 1 mile from Byron Station, Contra Costa County.	1		Cold to 135	Saline, sulphureted, and carbonated.	Do.
California Seltzer Spring, Mendocino County.				Alkaline, carbonated.	Do.
Calistoga Hot Springs, Calistoga, 9 miles south of Saint Helena, Napa County.	20		97	Saline	Once a resort.
Campbell's Springs (?), Sierra County					
Campo Chalybeate Spring					
Carbonated Spring, north part of Siskiyou County, on Shovel Creek Road.					
Castalian Mineral Water (Owen's Lake?) Inyo County.	13		Cold	Alkaline, sulphureted.	Used commercially and as a resort.
Castle Rock Springs, near Mount Shasta, Shasta County.				Sulphureted	
Chalybeate springs:					
Two miles from Tom's Head Mountain, Tehama County.					
Northwest of Fort Crook, on branch of Bear Creek, near head of Falls River, Shasta County.					
Coal Valley Boiling Springs, 8 miles west of Canby, Modoc County.					
Cold Soda Lake and Hot Springs, head of Mill and Battle Creeks, south of Lassen's Peak, Plumas County.					
Cook's Springs, Indian Valley, Colusa Co.				Sulphureted, &c.	
Crystal Springs (?), Napa County					
Crystal Springs, San Mateo County				Alkaline	
De Luz Hot Springs, near Oceanside, San Diego County.					Unimproved.
Desert or Cave Spring, Kern County				Borax spring, alkaline.	
Dr. Soupan's Hot Sulphur Spring, branch of Battle Creek, at head of road, Plumas County.				Sulphureted	
El Paso de Robles Hot and Cold Sulphur Springs, San Luis Obispo Co.	5		110 to 140	Sulphureted, saline, and chalybeate.	Resort.
Fresno Hot Springs, near Warthan, Fresno County.					
Fry's Soda Spring, near line of Shasta County, Siskiyou County.			52	Alkaline, carbonated.	
Fulton Wells, 3 miles north of Norwalk Station, Los Angeles County.	2			Sulphureted	Do.
Geysers:					
Near mouth of Willow and Warner Creeks, Plumas County.					
In extreme western end of Long Valley, on South Branch of Owen's River, Mono County.					
On Pluton Creek, northeast part of Sonoma County.			200 to 210	Saline, sulphureted, &c.	Do.
Geyser Springs, Geyser Springs, Sonoma County.	30	1,000	212	Alkaline	Used commercially and as a resort.

Mineral springs of California—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Geyser Soda Spring, Litton's Station, Sonoma County.[1]	1		° 27		Used commercially and as a resort.
Gilroy Hot Springs, 9 miles northeast of Gilroy, Santa Clara County.			109 to 115		Resort.
Glen Alpine Mineral Springs, near Falling Leaf Lake, south of Lake Tahoe, El Dorado County.				Alkaline, carbonated.	
Gordon's Spring, Lake County					
Grizzly Cañon Springs, east of Clear Lake, Lake ? County.					
Harbin Springs, Lake County, 20 miles north of Calistoga.			118 to 120	Saline, sulphureted.	Do.
Hatchinhama Lake, 4 miles west of Borax Lake, southeast of Clear Lake, Lake Co.				Alkaline	
Hensley's Mineral Springs, Tehama Co.				Chalybeate	
Hibbs's Soda Springs, 62 miles north of Redding, Shasta County.					
Highland Springs, Highland Springs, Lake County.	10		60 to 82	Alkaline	Do.
High Rock Spring, 9 miles east of Honey Lake, Lassen County.			100		
Hot Borate Spring, near Lakeport, Lake County.	1	18,000		Alkaline, saline.	
Hot Mud Springs, on Shovel Creek, near the State line, Siskiyou County.				Sulphureted	Do.
Hot springs:					
Two miles north of Fort Bidwell, Modoc County.					
In Surprise Valley, east side of Middle Alkali Lake, opposite Cedarville, Modoc County.			180		
Three miles east of Canby, Modoc Co.				do	
On east side of Middle Alkali Lake, 7 miles southeast of Cedarville, Modoc County.					
At base of Warner range, south end of Lower Alkali Lake, Modoc Co.					
On west side of Lower Alkali Lake, Modoc County.					
Between Upper and Middle Alkali Lakes, Modoc County.					
Nine to 13 miles northwest of Bridgeport, Mono County.					
One and a half miles southeast of Bridgeport, Mono County.					
Near Benton, Mono County			138		
In Long Valley, 5 miles east of Geyser, Mono County.					
On east side of Hot Spring Cove, Paoha Island, Mono Lake, Mono Co.			110		
In Amador County, in valley west of Markleeville.					
Four miles south of Bear Valley, Colusa County.					
On east and west sides of Owen's River, in valley south of Bishop's Creek, Inyo County.					
Six miles west of Panamint, Inyo Co.					
On Armagosa Creek, west of Dry Salt Lake, Inyo County.					
Seven miles southwest of Kernville and 5 miles northwest of Havilah, Kern County.					
South of Rafael Peak, Ventura Co.			195		
Five miles south of Santa Barbara, Santa Barbara County.			112 to 118	Sulphureted	Monticello Hot Springs ?
Head of Warner's Creek, southeast of Lassen's Peak, Plumas County.					

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[1] Probably same as Geyser Spa Spring in list of analyses.

Mineral springs of California — Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Hot springs—Continued.			°		
Near head of Battle Creek, south of Lake Cañon, Plumas County.			85		
In Plumas County				Sulphureted, carbonated.?	
At bend of San Jacinto River, in northwest part of San Diego Co.					
Between Clear Creek and Pitt River, near Big Valley or Bieber, Lassen County.	2				
Ten or 12 miles northeast of San Juan Capistrano, Los Angeles Co.			120 to 123		
Seven miles below Kernville, near Kern River, Kern County.			127	Sulphureted	
On summit of Mount Shasta, Siskiyou County.			180	do	
Hough's Spring, Hough Springs, Lake Co.			Cold		Resort.
Howard Springs, 3 miles from Adams Spring, Lake County.	14		58 to 109	Saline, chalybeate, &c.	Do.
Iron Spring, 2 miles north of Tom's Head Mountain, Tehama County.					
Lane's Spring, Stanislaus County					
Lane Mineral Springs, Calaveras Co.					
Las Cruces Hot Sulphur Spring, 42 miles from Santa Barbara, Santa Barbara Co.	1	500	90	Sulphureted	Used locally.
Little Geysers, 3 or 4 miles below the Geysers, Sonoma County.			190 to 200		
Litton's Seltzer Spring, Litton's Station, near Healdsburg, Sonoma County.	1	20		Carbonated, alkaline.	Used commercially and as a resort.
Little Yosemite Soda Springs, North Fork of Kern River, Tulare County.			52	Carbonated and chalybeate.	
Lower Soda Spring, in Sacramento Valley, opposite mouth of Castle Creek, Shasta County.				Carbonated	
Madrone Mineral Spring, 6 miles north of Gilroy Hot Springs, Santa Clara Co.				do	Resort.
Magnetic Springs,? near Watsonville, Santa Cruz County.					Used commercially
Mark West Springs, America, on Mark West Creek, Sonoma County.	10	90		Thermal, sulphureted, and chalybeate.	Resort.
Matilija Hot Springs, 6 miles from Nordhoff, Ventura County.	28	8,000+	35 to 160	Sulphureted	Do.
Mineral Spring of Grizzly Cañon, Lake County, near Wilbur Springs.					
McCarthy's Hot Springs, near Day's ranch, northeast of Fort Crook, Shasta County.					
Mills's Mineral Springs, 1 mile above Anderson's Springs, Lake County.	4		170	Saline, sulphureted.	Used locally as a resort.
Mineral springs:					
Twelve miles north of Wigginsville, Siskiyou County.					
On east slope of Mount Shasta, Siskiyou County.			Cold	Chalybeate	Unimproved.
West of Butteville, Siskiyou County					
On mountain, near Silver Lake, Alpine County.					
In Salt Spring Valley, Calaveras Co.					
West Shore of Mono Lake, Mono Co			Calcic		
On Encino ranch, Los Angeles Co		83 to 87		Alkaline, carbonated.	
Three miles above Mouth of Little Creek Cañon, San Bernardino Co.		92			
Mono Basin Warm Springs, northeast shore of Mono Lake, Mono County.			85 to 90	Saline, alkaline	
Mono Lake, Mono County					Strongly mineralized.
Mountain Glen Hot Springs, 25 miles north of Santa Barbara, Santa Barbara County.			60 to 100	Sulphureted	Local resort.

Mineral springs of California—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Mud springs:			°		
Fifteen miles northeast of Honey Lake, Lassen County.					
On Antelope Creek, 10 miles east of Red Bluff, Tehama County.					
Napa Soda Springs, 7 miles from Napa City, Napa County.	27		68	Carbonated, saline.	Used commercially and as a resort.
Newsom's Arroyo Grande Warm Springs, 2 miles from Arroyo Grande, San Luis Obispo County.	3+	49,000?	40 to 100	Sulphureted	Resort.
Owen's Lake, south end of Owen's Valley, Inyo County.				Alkaline	
Pacific Congress Springs, 12 miles west of San José, Santa Clara County.			50	Saline, chalybeate.	Used commercially and as a resort.
Paert's Hot Springs, near Benton, Mono County.					
Paraiso Spring, Paraiso Springs, 7 miles south of Soledad, Monterey County.			118	Saline	Resort.
Pearson's Springs, 1 mile west of Witter's Spring, Lake County.	5		Cold	Alkaline, sulphureted.	Small resort.
Petroleum Spring, west shore of Hot Spring Cove, on island of Paoha, Mono Lake, Mono County.			96		
Piedmont White Sulphur Springs, 3 miles from Oakland, Alameda County.					
Salt Lake, east of Geyser, in Long Valley, Mono County.					
Salt springs:					
North of Inyo range, east of Black Mountain, Inyo County.					
East side Panamint Valley, Inyo Co.					
Eight miles south of bend of Furnace Creek, east side of Death's Valley, Inyo County.					
Near Armagosa Mines, San Bernardino County.					
On Salt Creek, Tehama County					
Northeast of Patterson's Pass, Alameda County.					
On south side of Mokelumnè River, 6 miles south of Silver Lake, Calaveras County.					
Eighty miles from Red Bluff, on Branch of Stony Creek, Trinity Co.					
Salt Wells, in Salt Wells Valley, between Borax Flats and Indian Wells, San Bernardino County.					
San Bernardino Hot Springs, north of San Bernardino, San Bernardino County.			108 to 172	Calcic	
San Marcos Sulphur Springs, 7 miles northwest of Santa Barbara, Santa Barbara County.					
San Rafael Springs, San Rafael, Marin County.					
Santa Barbara Hot Sulphur Springs, 6 miles from Santa Barbara, in Santa Ynez Mountains, Santa Barbara Co.	7		112 to 117	Sulphureted	Used locally.
Saratoga Spring, south end of Funeral Range, south of Death Valley, Inyo County.				Thermal	
Seigler Springs, near Adams Spring, Lake County.				Chalybeate	Resort.
Shafer's Hot Springs, north end of Henry Lake, Lassen County.			210		
Simmons's Hot Sulphur Springs, Sulphur Cañon, near Wilbur Springs, Colusa Co.			170	Sulphureted	Has a local reputation.
Skaggs's Hot Springs, 6 or 8 miles from Geyserville, Sonoma County.	3+	900	128 to 140	Carbonated	Used commercially and as a resort.
Soda Lake in Saline Flats, on Mojave River, San Bernardino County.					
Soda Pond, north of Salt Lake, in Long Valley, Mono County.					

Mineral springs of California — Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Soda springs:			°		
Eight miles below Salt Springs, east side of Death's Valley, Inyo Co.					
Eight miles east of Clear Lake, Lake County.					
On Linkville and Yreka Road, Siskiyou County.				Alkaline, carbonated.	
At Soda Bar, 2 miles from Oregon line, Siskiyou County.				do	
Southwest of Volcano Springs, San Diego County.					
East of Volcano Springs, San Diego County.					
At Forks of McCloud River, Shasta County.				Alkaline, carbonated.	
East of Lower Soda Springs, on branch of McCloud River, Shasta County.				do	
On Sacramento River, Siskiyou Co., near Shasta County line.			52	do	
Three miles northeast of Little Shasta, Siskiyou County.				do	
Nine miles west of Tuolumne River, west of Mono Pass, Tuolumne Co.				do	
Springs of Dos Palmas, in Coahuila Valley, San Diego County.			82	Saline	
Steamboat Springs, southeast of Lassen's Peak, Plumas County.					
Stewart's Hot Springs, in Warm Spring Valley, Modoc County.					
Sulphur springs:					
Four miles southwest of Tom's Head Mountain, Tehama County.					
West of San Fernando Peak, Ventura Co.					
Seven or eight miles east of Watsonville, Santa Cruz County.					
On Brown's Creek, Shasta County, southeast of Douglass City.					
On South Branch of West Fork of Sacramento. Shasta County.					
Few miles above mouth of Castle Creek, Shasta County.					
In Black Cañon, 3 miles north of Canby, Modoc County.					
Thirty miles south of Tulare Lake and 1 mile northwest of Buena Vista Lake, Kern County.					
Eight or ten miles west of south end of Tulare Lake, Kern County.				Saline	
On south side of San Fernando Mountain, Los Angeles County.					
Eight miles north of Black Butte, southern part of Shasta Valley, Siskiyou County.					
Seven miles north of county line, Monterey County, 20 miles from San Miguel Mission.					
In Mohawk Valley, Plumas County					
Near Dry Lake, 15 miles northwest of Camp Cody, San Bernardino Co.					
Northeast of San Luis Mountains, San Luis Obispo County.					
Ten miles northeast of San Miguel Mission, San Luis Obispo County.					
Six miles south of McCormick's well, in Desert Valley, Inyo Co.					
South of Resting Spring, Inyo Co					
Summit Soda Springs, near Soda Springs Station, Alpine County (?).			Cold	Alkaline, carbonated.	Not open now.
Tahoe or Cornelian Springs, on Lake Tahoe, near State line, Placer County.			131		Resort.
Tassajara Hot Springs, head of Arroyo Seco, Monterey County.					

Mineral springs of California—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	**Remarks.**
			°		
Thermal Acid Springs, in Coso Range, 12 miles east of Little Owen's Lake, Inyo County.	......	......	......	......	
Thermal springs:					
On Battle Creek, 5 miles above Morgan's Ranch, Plumas County.	......	......	......	......	
On Owen's River, opposite Black Rock, Inyo County.	......	......	......	......	
Near mines of Darwin, Inyo County	......	......	......	......	
Ten miles east of Telescope Peak, Inyo County.					
Tolenas Springs, 5 miles north of Suisun City, Solano County.	19	600+	65	Alkaline, carbonated.	Used commercially and as a local resort.
Tule River Soda Springs, South Fork of Tule River, east of Portersville, Tulare County.	......	......	......	...do	
Tuscan or Lick Springs, 9 or 10 miles northeast of Red Bluff, Tehama Co.	3+	......	66 to 80	Saline, sulphureted.	Local resort.
Ukiah Vichy Springs, 32 miles from Cloverdale, 2 miles from Ukiah, Mendocino County.	......	......	81 to 90	Carbonated	Resort.
Vallejo Sulphur Springs, Vallejo, Solano County.	......	......	80 to 90	......	
Vichy Springs of New Almaden, Santa Clara County, 50 miles south of San Francisco.	......	......	......	Alkaline, carbonated.	Do.
Volcanic Springs, near Volcano Station, Southern Pacific Railroad, San Diego County.	......	......	......	......	
Warm springs:					
Near head of Walker's Basin, Kern County.	......	......	100	......	
In Warm Spring Valley, 10 miles west of Alturas, Modoc County.	......	......	......	......	
On east side Pit River, on Hot Creek, north of Round Valley, Modoc Co.	......	......	......	......	
Twelve miles southwest of Camp Cody, San Bernardino County.	......	......	......	......	
Near Little Owen's Lake	1	......	......	Alkaline......	
Nine miles from Amargosa mines, Inyo or San Bernardino County.	......	......	......	......	
Southwest of Pittville, Lassen Co...	......	......	......	......	
Warm Sulphur Springs, near Simms Valley, on Posa Creek, Kern County.	......	......	......	......	
Warner's Ranch Spring (Agua Caliente), 30 miles from San Diego, San Diego County.	......	1,400?	74 to 142	Sulphureted.....	Local resort.
Waterman's Springs, ½ mile west of Arrowhead, San Bernardino County.	......	......	......	......	Private.
White sulphur springs:					
In Napa Valley, 2½ miles south of Saint Helena, Napa County.	9	......	69 to 89.6	Sulphureted.....	Resort.
Two miles north of Plymouth, Amador County.	......	......	......	......	
At edge of Panamint Range, 12 miles north of Panamint, Inyo County.	......	......	......	......	
In Santa Rosa, Sonoma County.....	......	......	......	......	
In Bear Gulch, west or southwest of Red Bluff, Tehama County.	......	......	......	......	
Wilbur Springs, 30 miles from Colusa, Colusa County.	......	......	......	Sulphureted.....	Has a local reputation.
Witter's Springs, 5 miles from Upper Lake, 3 miles from Blue Lake, Lake County.	......	......	Cold..	Sulphureted, chalybeate.	Small resort.
Zem Zem Springs, southeast of Clear Lake, Lake County.	......	......	64	Saline?.........	

Analyses of mineral springs in California.

Constituents.	Adams Spring.	Ætna Springs.	Castalian Mineral Water.	California Seltzer Spring.	Calistoga Hot Springs.
	Grains per gallon.[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]	*Grains per gallon.*[d]	*Grains per gallon.*[e]
Sodium carbonate	57.04	75	1,724.11		3.41
Sodium bicarbonate				58.20	
Magnesium carbonate	99.02	14		45.20	
Calcium carbonate	28.71	10		70.40	
Iron carbonate	0.52			Trace	
Sodium sulphate		08	651.02		
Potassium sulphate					1.61
Magnesium sulphate					0.47
Sodium sulphide			46.34		
Sodium chloride	4.11	29	1,840.72	17.20	22.25
Potassium chloride			132.30		
Calcium chloride					3.26
Lime			Trace		
Magnesia			Trace		
Alumina					Trace
Silica	7.22	Trace	14.28	Trace	6.58
Boracic acid			Trace		
Phosphoric acid			Trace		
Nitric acid	Trace				
Potassium	Trace				
Iodine			Trace		
Bromine			Trace		
Iron			Trace		
Organic matter	2.81		13.48		
Total	199.48	136	4,422.25	186.00	37.58
Gases.	*Cubic inches.*	*Cubic inches.*			*Cubic inches.*
Carbonic acid	304.00	58		Abundant	
Sulphureted hydrogen					3.271

Constituents.	Thermal Acid Springs, Coso Range.	Springs of Dos Palmas.	El Paso De Robles Springs.		Fulton Wells.
			Hot Sulphur Spring.	Mud Spring.	
	Parts in 100,000.[f]	*Parts in* 100,000.[f]	*Grains per imp. gallon.*[g]	*Grains per imp. gallon.*[g]	*Grains per gallon.*
Sodium carbonate				5.21	
Sodium bicarbonate			50.74		2.20
Magnesium carbonate				3.10	
Magnesium bicarbonate			0.92		16.50
Calcium carbonate		Trace			
Calcium bicarbonate					12.00
Iron subcarbonate					13.00
Sodium sulphate	15.1		7.85	41.11	
Potassium sulphate	2.5		0.88	Trace	
Calcium sulphate	15.3	32.6	3.21	17.90	
Magnesium sulphate	1.2	31.0			
Aluminium persulphate	127.0				
Iron persulphate	33.2				
Sodium sulphide					0.90
Sodium chloride		230.8	27.18	96.48	10.40
Lithia	Trace				
Iron peroxide			0.36		
Ammonia	Trace				
Alumina			0.22		
Silica		Trace	0.44	1.11	
Phosphoric acid	Trace	Trace			
Nitric acid	Trace				
Sulphuric acid	78.4				
Sulphur					23.00
Chlorine	Trace				
Iodine			Trace		
Bromine			Trace		
Manganese		Trace			
Organic matter			1.64	3.47	
Total	272.7	294.4	93.44	168.38	78.00
Gases.			*Grains.*	*Grains.*	
Carbonic acid			10.50	47.84	Abundant
Sulphureted hydrogen			4.55	3.28	Abundant

[a] Thomas Price, analyst.
[b] J. A. Bauer, analyst.
[c] Thomas Price, analyst (1880).
[d] F. A. Bower (?), analyst.
[e] J. F. Rudolph, analyst.
[f] Oscar Loew, analyst (1876).
[g] Price and Hewston, analysts.

Analyses of mineral springs in California—Continued.

Constituents.	Azule Mineral Springs.	Geyser Spa Spring.	Hot Borate Springs.	Napa Soda Springs.
	Grains per gallon.	*Grains per gallon.*[a]	*Grains per gallon.*[b]	*Grains per gallon.*[c]
Sodium carbonate	50.88			
Sodium bicarbonate		23.48	76.96	13.12
Magnesium carbonate	77.20			26.12
Magnesium bicarbonate		9.80		
Calcium carbonate	9.00	4.56		10.88
Iron carbonate		3.80		
Iron subcarbonate				7.84
Ammonium bicarbonate			107.76	
Sodium sulphate		3.40		1.84
Calcium sulphate			Trace	
Sodium biborate			108.29	
Sodium chloride	90.88	9.96	84.62	5.20
Potassium chloride	12.44		Trace	
Magnesium chloride	18.48			
Magnesium iodide			0.09	
Magnesium bromide			Trace	
Alumina			1.26	0.60
Silica		1.80	8.23	0.68
Volatile matter			65.77	
Carbonic acid	152.24		36.87	
Loss		0.32		2.48
Total	411.12	57.12	484.85	68.76

Constituents.	Pacific Congress Springs.	Vichy springs of New Almaden.	Litton's Seltzer Spring.	Skaggs's Hot Springs.
	Grains per gallon.[d]	*Grains per gallon.*	*Grains per gallon.*[e]	*Grains per gallon.*[f]
Sodium carbonate	123.85	200.12		
Sodium bicarbonate				161.27
Magnesium carbonate				11.11
Calcium carbonate	17.29	32.00		2.20
Lithium carbonate				0.06
Iron carbonate				0.05
Iron bicarbonate	14.03			
Barium carbonate				0.24
Strontium carbonate				0.02
Sodium sulphate	12.14			
Potassium sulphate				0.26
Calcium sulphate		40.20		
Magnesium sulphate		12.00		
Sodium biborate				26.47
Sodium chloride	119.16	32.16		5.90
Potassium chloride				0.20
Sodium iodide				Trace
Soda			62.19	
Lime			4.41	
Magnesia	Trace		5.24	
Iron oxide			2.85	
Alumina	} 49.88			0.01
Silica	}		2.92	7.02
Carbonic acid		112.08	42.96	
Sulphuric acid			2.36	
Chlorine			78.38	
Iron		4.08		
Organic matter			[g]27.38	
Total	335.85	432.64	228.69	214.81

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[a] Bauer or Price, analyst.

[b] Moore, analyst.

[c] L. Lanzwurt, analyst.

[d] Bauer (?), analyst.

[e] Henry G. Hanks, analyst.

[f] E. W. Hilgard, analyst.

[g] Potassa, lithia, ammonia, alumina, and boracic acid included.

Analyses of mineral springs in California—Continued.

Constituents.	Highland Springs.			Little Yosemite Soda Spring.	Mineral Spring, Encino Ranch.
	Seltzer Spring.	Dutch Spring.	Magic Spring.		
	Grains per gallon.[a]	*Grains per gallon.*[a]	*Grains per gallon.*[a]	*Parts in* 100,000.[b]	*Parts in* 100,000.[b]
Sodium carbonate	8.87	12.72	15.10	20.97	24.31
Magnesium carbonate	20.67	40.08	41.63	16.02	32.17
Calcium carbonate	34.76	39.80	35.02		
Potassium carbonate	0.38	0.58	0.42		
Manganese carbonate	Trace	Trace	Trace		
Iron carbonate	0.92	0.98	0.78	0.92	
Sodium sulphate				Trace	54.46
Sodium chloride	0.72	1.65	1.28	4.68	2.93
Alumina	1.56	0.11	0.17		
Silica	5.24	7.12	7.39	7.31	11.50
Phosphoric acid					Trace
Sulpho-hydric acid					Trace
Potassium					Trace
Lithium					Trace
Organic matter	Trace	Trace	Trace		
Total	73.12	108.04	101.79	49.90	125.37
Gas.					
Carbonic acid	*Cubic inches.* 212.20	*Cubic inches.* 184.80	*Cubic inches.* 156.80	In excess	In excess

Constituents.	Mono Lake.	Hot Spring on Paoha Island, Mono Lake.	Soda Lake, Saline Flats on Mojave River.	Sulphur Spring, south side of San Fernando Mt.	Mono Basin Warm Springs.
	Grams per liter.[a]	*Grams per liter.*[a]	*Parts in* 100,000.[b]	*Parts in* 100,000.[b]	*Grams per liter.*[c]
Sodium carbonate	19.4900	0.0506		6.21	0.5972
Magnesium carbonate	0.3600				
Magnesium bicarbonate		0.0154		50.60	0.2114
Calcium carbonate	0.6800	0.1035			0.1475
Sodium sulphate	10.0700	0.0799	63.1	23.87	0.4631
Calcium sulphate			21.2		
Magnesium sulphate			8.5		
Sodium biborate	0.2000				
Sodium silicate					0.2480
Sodium chloride	18.2200	0.0104	170.8	Trace	0.2790
Potassium chloride	2.2300	0.0169			0.1203
Alumina				Trace	0.0018
Silica	0.2800	0.0178	Trace	Trace	
Phosphoric acid			Trace	Trace	
Sulpho-hydric acid				5.00	
Potassium			Trace	Trace	
Lithium			Trace	Trace	
Iron				Trace	
Manganese				Trace	
Organic matter			19.0	Trace	
Loss	0.3200				0.0156
Total	51.8500	0.2945	282.6	85.68	2.0850
Gas.					
Carbonic acid				In excess	

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[a] Prof. Rising, analyst. [b] Oscar Loew, analyst, 1876. [c] T. M. Chatard, analyst.

Analyses of mineral springs in California—Continued.

Constituents.	Santa Barbara Springs.		San Bernardino Springs.	
	No. 1, main spring, Hot Spring Cañon.	No. 2, main spring, Side Cañon.	No. 1, large spring in front of hotel.	No. 2, spring 200 yards west of hotel.
	Parts in 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]
Sodium carbonate	29.6	24.8		
Magnesium carbonate			Trace	Traces
Calcium carbonate			10.7	11.0
Iron carbonate			Trace	Traces
Sodium sulphate	5.0	Trace	81.7	80.2
Potassium sulphate			2.3	Trace
Sodium chloride	8.7	7.6	12.8	13.4
Potassa	Trace	Trace		
Silica	4.2	6.0	20.5	22.4
Carbonic acid	Trace	Trace		
Sulpho-hydric acid	Trace	Trace		
Calcium	Trace	Trace		
Total	47.5	38.4	128.0	127.0

Constituents.	Springs near San Juan Capistrano, main spring.	Agua Caliente of Cabeson Valley.	Warm Spring, near Little Owen's Lake.	Ukiah Vichy Springs.
	Parts in 100,000.[a]	*Parts in* 100,000.[a]	*Parts in* 100,000.[a]	*Grains per gallon.*[b]
Sodium carbonate	11.10	8.3	45.2	197.75
Magnesium carbonate			Trace	22.64
Calcium carbonate			12.0	17.85
Sodium sulphate	Trace	Trace	8.0	Trace
Potassium sulphate				Trace
Sodium chloride	10.53	31.0	26.9	27.51
Potassium chloride				Trace
Potassa	Trace		Trace	
Lime	Trace	Trace		
Magnesia	Trace	Trace		
Lithia	Trace	Trace		
Iron				Trace
Alumina				
Silica	7.66	Trace	Trace	6.86
Sulpho-hydric acid		Trace		
Organic matter		Trace	Trace	
Total	29.29	39.3	92.1	272.61

[a] Oscar Loew, analyst (1876).

[b] John Hewson, jr., analyst.

Analyses of mineral springs in California—Continued.

Constituents.	Summit Soda Spring.	White Sulphur Springs, Saint Helena.		
		Spring No. 2.	Spring No. 6.	Spring No. 7.
	Grs. per gall.[a]	*Grs. per gall.*[b]	*Grs. per gall.*[b]	*Grs. per gall.*[b]
Sodium carbonate	9.50			
Magnesium carbonate	4.20	0.62	0.56	4.36
Calcium carbonate		1.25	2.44	5.56
Calcium bicarbonate	43.20			
Sodium sulphate		8.26	11.33	12.84
Sodium sulphide		2.65	1.85	1.62
Calcium sulphide				
Sodium chloride	26.22	21.72	23.41	14.23
Calcium chloride		1.32	0.86	0.78
Magnesium chloride		0.87	2.22	0.65
Potassa	Trace			
Iron oxide	1.75			
Alumina	1.75			
Silica	2.06			
Total	88.68	36.69	42.67	40.04
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Sulphureted hydrogen	186.35	6.15	4.25	Trace

Constituents.	Paraiso Spring.	Volcanic Springs.	Tolenas Springs.	Shafer's Hot Springs.
	Grs. per gall.[c]	*Grs. per gall.*[d]	*Grs. per gall.*[e]	*Grams per liter.*[f]
Sodium carbonate	4.23	1,724.11	53.36	
Magnesium carbonate			10.88	
Calcium carbonate	1.48		48.32	
Iron carbonate			0.64	
Sodium sulphate	35.50	651.02		0.4715
Calcium sulphate	4.82			0.0409
Magnesium sulphate				0.0020
Sodium biborate			20.56	
Sodium silicate				0.0613
Sodium sulphide		46.34		
Sodium chloride	3.50	1,840.72	215.92	0.3266
Potassium chloride	0.85	132.30	5.68	0.0180
Potassium iodide			2.08	
Lime		Trace		
Magnesia	Trace	Trace		
Iron oxide	1.60	Trace		
Alumina			0.96	
Silica	2.62	14.28	1.60	0.1008
Boracic acid		Trace		
Phosphoric acid		Trace		
Iodine		Trace		
Bromine		Trace		
Organic matter	5.25	13.48		
Total	58.80	4,422.25	360.00	1.0211

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[a] J. F. Rudolph, analyst.

[b] J. Le Conte, analyst (1871).

[c] A. Cihi, analyst (1871).

[d] Dr. Price, analyst.

[e] John Hewson, jr., analyst.

[f] F. W. Clarke, analyst (1883).

OREGON.

Oregon is well supplied with valuable mineral springs, both hot and cold. The thermal springs are numerous, and, as in Nevada and Utah, are found mainly in connection with faulted strata. Carbonated springs are also frequently found, and, with alkaline and sulphureted waters, comprehend most of the varieties found in the State. Chittenden's Health and Pleasure Resorts of the Pacific Coast for 1879 contains the best list heretofore published, but it is not complete for the present time. The present list has been made up mainly from reports obtained directly from the localities. Various maps have also been consulted, and Mr. Mark B. Kerr and Mr. Eugene Ricksecker have furnished data as to springs in the southern counties of the State. A considerable number of the springs have been improved and are utilized as resorts.

Mineral springs of Oregon.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Aurora Saline Springs, 1½ miles west of Aurora Mills, Marion County.	2	600	° 57	Calcic, saline ...	Used to some extent as a resort.
Belknap Hot Springs, near McKinzie Bridge, Lane County.	7	1,260	184	....	Resort.
Canter's Blue Sulphur Springs, Jordan Valley, Baker County, west of Silver City, Idaho.	8	....	200	....	Used as a local resort.
Cole's Soda Springs, 3 miles west of White Point, Jackson County.	....	....	......	....	Resort.
Cooper's Springs, 1 mile east of Wilbur, Douglas County.	...	....	......	....	Unimproved.
Cullen's Springs, Yam Hill County	....	....	......	....	
Des Chutes Hot Springs, 8 miles north of Warm Spring, Crook County.	....	....	143 to 145	Alkaline, saline.	Do.
Foley Springs, near McKinzie Bridge, Lane County.	...	....	188	....	Resort.
Hot springs:					
Near Lakeview, Lake County......	....	....	......	....	
On Malheur River, near mouth, Baker County.	1+	....	193	....	
At base of Stein Mountains, Grant County.	....	....	168	....	
At north end of Quinn River Valley, Baker County.	....	....	......	....	
On northwest side of Goose Lake, Lake County.	....	....	......	....	
In Warner Lakes Valley, Grant Co.	....	....	......	....	
Four miles south of Lakeview, Lake County.	....	....	......	....	Local resort.
On Cheeseman's Ranch, 1 mile north of Lakeview, Lake County.	....	....	......	....	Do.
Kitson's Springs, Dexter, Lane County.	....	....	......	....	
Linkville Springs, near Linkville, Klamath County.	4+	....	Hot	....	One is improved; used as a resort.
Lower Soda Spring, south fork of Santiam River, Linn County.	....	....	......	Alkaline, carbonated.	Resort.
Malheur River Springs, branch of Malheur River, Baker County.	....	....	......	....	
McCalister's Soda Springs, 35 miles east of Jacksonville, Jackson County.	....	60	......	....	Used commercially and as a resort.
Mineral springs:					
Twelve miles east of Jacksonville, Jackson County.	....	....	......	Carbonated.....	

Mineral springs of Oregon—Continued.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
Mineral springs—Continued.			°		
On West Fork of Beaver Creek, Jackson County.	2			Chalybeate and carbonated.	Unimproved.
Three miles south of Aurora Mills, Marion County.					
In Willamette Valley, 50 miles above Eugene City, Lane County.	2				Resort.
On Blue Mountains, near John Day, Grant County.	1		120		Do.
Six miles southeast of Astoria, Clatsop County.				Carbonated	
In Sam's Valley, Jackson County				Sulphureted	
On W. Allen's farm, near East Portland, Multnomah County.				Chalybeate	
Payton or Snowden Mineral Spring, 2 miles south of Drain's Station, Douglas County.	1	225	57	Alkaline	Used commercially and as a resort.
Soda springs:					
Near Jacksonville, Jackson Co				Carbonated	Do.
At Waterloo Falls, 8 miles above Sodaville, Linn County.				do	Unimproved.
Six miles from Ashland, Jackson Co.					
At Brownsborough, Jackson Co					
On Molalla River, Clackamas Co					
Sodaville Spring, Sodaville, Linn Co	1	15	45	Carbonated	Free resort.
Solfataire, near Linkville, Klamath Co.					Used for vapor baths.
Sulphur springs:					
At Sulphur Springs, on Smith's Fork of Umpqua River, Douglas County.					Unimproved.
One mile above Sulphur Springs Douglas County.					Do.
Upper Soda Springs, Santiam River, 10 miles above Lower Soda Springs, Linn County.					
Warm springs:					
Northeast of Summerville, Union County.					
West of Malheur Lake, Grant Co					
In Summit Lake Valley, Lake Co.					
Wilhoit's Soda Springs, Clackamas Co., Rock Creek, 25 miles northeast of Salem.	7	700+	85	Alkaline	Used commercially and as a resort.
White Sulphur Springs, head of Clackamas River, Clackamas County.					
Hot springs:					
In Horsefly Valley, southwest of Drew's Valley, Lake County.					
On Lost River, west of Bonanza, Lake County.					

Analyses of mineral springs in Oregon.

Constituents.	Des Chutes Hot Springs.	Wilhoit's Soda Springs.	Aurora Saline Springs.	Foley Springs.
	Grs. per gall.[a]	*Grs. per gall.*[b]	*Grs. per gall.*[c]	*Grs. per gall.*[d]
Sodium carbonate	34.50	87.57		
Magnesium carbonate		85.32		
Calcium carbonate		32.23	Trace	
Iron protoxide carbonate		6.00		
Sodium sulphate	9.46	3.40		
Magnesium sulphate		6.45		
Calcium sulphate	1.82			
Sodium chloride	20.42	201.00	356.00	75.00
Potassium chloride	2.00			
Magnesium chloride	1.21		19.87	
Sodium silicate	8.20			
Iron	Trace			
Iodine		Trace		
Calcium chloride			474.13	90.00
Iron carbonate			Trace	
Silica			10.61	
Organic matter			1.01	
Undetermined				21.00
Total	77.61	421.97	861.62	186.00
Gas.	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*	*Cubic inches.*
Carbonic acid	22.56	3.3844		

Constituents.	Kitson's Springs.		Cooper's Springs.	Payton Mineral Spring.
	Cold Spring.	Hot Spring.		
	Grs. per gall.[d]	*Grs. per gall.*[d]	*Grs. per gall.*[d]	*Grs. per gall.*[e]
Magnesium sulphate Calcium sulphate	[f]28.00			
Sodium chloride	180.00	208.00	128.00	113.00
Magnesium chloride				145.00
Calcium chloride	48.00	64.00	190.00	115.00
Iron carbonate				[g]62.00
Undetermined matter		42.00	[h]34.00	
Total	256.00	314.00	352.00	435.00

[a] L. N. Dornbach and E. N. Horsford, analysts.

[b] J. A. Veatch, analyst (1869).

[c] J. H. Bell, analyst (1870).

[d] R. G. Rex, analyst.

[e] Philip Harvey, analyst (1876).

[f] With insoluble matter.

[g] With calcium, carbonate and loss.

[h] With magnesia, alumina, and silica.

WASHINGTON.

The list of mineral springs for Washington Territory is as yet small, and, so far as known, this is the first attempt to enumerate them. Walton mentions but one locality, viz, Medical Lake, which is at present the only one at which the water is put up for sale. The water is condensed and bottled and the evaporated salts are also put up in packages, which are extensively sold. There is but one other locality in the Territory used as a resort. As the country becomes more fully settled there will doubtless be other localities improved and many new ones added to the table.

The present list has been compiled partly from maps and partly from letters received from various portions of the Territory.

Mineral springs of Washington Territory.

Name and location.	Number of springs.	Flow in gallons per hour.	Temperature, Fahr.	Character of the water.	Remarks.
			°		
Alkaline Springs, in Crab Creek Coulée, Spokane County.					
Brackett Spring, Edmonds, Snohomish County.	1	65	57		Unimproved.
Cascade Warm Mineral Springs, Cascades, Skamania County.	4	160	96	Saline, sulphureted.	Resort.
Chalybeate Springs, Clallam County.					
Denny Springs, King County	2	1,640	48	Saline	Unimproved.
Hot springs:					
On Green River, west slope of Cascade Mountains, 50 miles north from Seattle, King County.					
Medical Lake, Medical Lake, Spokane County.			60	Alkaline, saline.	Used commercially and as a resort.
Pinkham Mineral Spring or Well, Lake Union, near Seattle, King County.				Calcic	
Saline Springs, east end of Rattlesnake Mountains, Yakima County.					
Salt and alkaline lakes:					
North of Saddle Mountain, Spokane County.					
North of Fort Okinakane, Stevens County.					
Soda Spring, near Goldendale, Klikitat County.					Unimproved and difficult of access.
Sulphur Lake, east of Palouse Junction, Whitman County.					
Sulphur Spring, southeastern part of Garfield County.					
Thermal Wells, Ainsworth, Whitman County.			60		

Analysis of mineral spring in Washington Territory.

Constituents.	Medical Lake.
	Grs. per gall.[a]
Sodium carbonate	63.543
Lithium carbonate	Trace
Magnesium carbonate	0.233
Iron carbonate	0.526
Calcium carbonate	0.186
Sodium chloride	16.370
Potassium chloride	9.241
Alumina oxide	0.175
Sodium metasilicate	10.638
Potassium sulphate	Trace
Sodium diborate	Trace
Organic matter	0.551
Total	101.463

[a] G. A. Mariner, analyst (1882).

ALASKA.

According to Dr. William H. Dall (from whose Alaska and Its Resources the list given here is mainly compiled), the hot and mineral springs of Alaska are both numerous and important. Besides the hot springs there are many which do not freeze even during the most severe winter weather, and which, therefore, are properly included under the head of thermal springs. Hot springs are most numerous on the list, which may be due partly to the fact that such springs naturally attract most attention, especially in a new country. Chalybeate, sulphureted, and saline springs are also found. The springs enumerated by Dall are supplemented in the table by several others, two of which are taken from a book by Frederick Whymper, one from the Pacific Coast Pilot for 1869, and two from Walton's Mineral Springs, in which they are reported by Dr. H. J. Phillips, of the United States Army. Several localities have been added by Sheldon Jackson. So far as learned, none of the waters of the Alaskan mineral springs has ever been analyzed.

Mineral springs of Alaska.

Name and location.	Temperature, Fahr.	Character of the water.	Remarks.
	°		
Boiling springs on northeast side of Akutan Island		Saline ?	
Boiling springs on Kánaga Island			Used by Aleuts from time immemorial for cooking purposes.
Boiling mud springs on Koni volcano, Atka Island		Sulphureted	
Chalybeate spring, ½ mile from Sitka, Baranoff Island.			
Chalybeate spring on west bank of Chilkat River, on the mainland.			
Geysers, or warm sulphur springs, Sitka Sound, 15 or 20 miles from Baranoff Island.	[a]153½	Saline and sulphureted.	Was used as the site of hospital by the Russians, and the springs were used extensively.
Hot springs, 5 miles from Korovni Bay, Aka Island	167	Saline ?	
Hot springs between Korovni and Klucheff volcanoes, Atka Island.			
Hot springs on Adakh Island			
Hot springs in Parenosa Bay, on south coast of Aliaska Peninsula.			
Hot springs in Port Möller, north side of Aliaska Peninsula.			
Hot spring in crater of Goreloi, Goreloi Island			
Hot springs on Amagat Island, near Aliaska Peninsula.			
Hot Springs on a small island southeast of Akhün			
Hot Springs on Chichagoff Island, east of Siwash passage.			Used by Aleuts for bathing.
Hot marshes near Pogrümnoi volcano, Unimak Island			
Hot springs on Stikine River, 25 miles above its mouth.			
Hot springs on Sitignak Island.			
Hot springs on Segouam ? Island			
Hot springs opposite Iliuluk or Captain's Harbor, on Unalaska Island.	94	Sulphureted	
Hot springs near Makushin Mountain, Unalaska Island.			
Hot Springs near Deep Bay, Unimak Island	212		Used for bathing by the Aleuts.
Intermittent boiling springs, in a small valley of Unimak Island.			
Saline lake on Beaver Island in the Pribyloff Group			
Sulphur lake on Unimak Island			
Warm springs on Unalaklik River, near Ulukuk	84	Saline ?	The temperature of the air was —8° Fahr.
Warm springs between Versola Sofke and Youkon River.			

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[a] This is the temperature given in the Coast Pilot. Dall gives a temperature of 122° F., and Dr. Phillips, in Walton's book, gives 96° F. to 104° F.

RECAPITULATION.

The totals in the following table are somewhat greater than those given in the summary on page 986 of Williams's Mineral Resources of the United States, 1883–'84, as additional data have been received since the publication of that report.

States.	Number of spring localities.	Number of individual springs.	Number of springs analyzed.	Number of springs utilized as resorts.	Number of springs used commercially.	Total number of analyses.
Northern Atlantic States ...	405	657	155	74	72	187
Southern Atlantic States ...	371	1,048	148	152	42	164
Southern Central States ...	721	1,911	137	174	36	146
Northern Central States	601	1,276	215	122	55	224
Western States and Territories.	724	3,951	132	112	18	138
Grand total...........	2,822	8,843	787	634	223	859

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NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume V.

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J. W. POWELL, DIRECTOR

78a

NOTES
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BY

J. S. DILLER

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., January 4, 1886.

SIR: Herewith I have the honor to transmit a paper by Mr. J. S. Diller, "Notes on the Geology of Northern California," and I recommend that it be published as a bulletin of the Geological Survey. During the last summer it was my privilege to go over a large part of the region to which his Notes refer, and I am entirely in accord with him so far as my opportunities for observation enabled me to judge. Mr. Diller's investigations have yielded valuable results, and already go far towards the elucidation of some of the broader and primary geological problems which are presented to the north of the northern end of the Sierra Nevada. They have resulted also in the collection of a very large amount of detailed information of high value.

Very respectfully, sir, your obedient servant,

C. E. DUTTON,
Captain of Ordnance, U. S. A.

The DIRECTOR OF THE U. S. GEOLOGICAL SURVEY.

GEOLOGY OF NORTHERN CALIFORNIA.

By J. S. Diller.

INTRODUCTORY.

Under the general supervision of Capt. C. E. Dutton, I have spent three field seasons in Northern California and Oregon among those complex groups of mountain ridges and ranges whose relations to one another have frequently been a subject of discussion, and it is in the hope of throwing some light upon the structure and connection of these ranges that I desire to note a few observations.

A hasty reconnaissance of both slopes and of most of the prominent peaks of the Cascade Range was followed by a more detailed examination of Mount Shasta and the neighboring elevations of the Coast and Sierra Nevada Ranges to a little beyond the fortieth parallel. The short but well defined volcanic ridge of Lassen's Peak appeared to afford an excellent field for studying some of the important problems of volcanology, and it was decided that this range, with the adjacent portions of the Sierra and Coast Ranges, should be subjected to careful investigation.

While tracing the southern limit of the lavas from this volcanic ridge a preliminary examination was made of the northern portion of the Sierra Nevada Range, and the results are considered of sufficient importance to warrant their presentation in advance of a more detailed study. The stratigraphy of the region is very complicated; before it can be properly discussed it is necessary to consider not only the general topographical features of the country but also the character and distribution of the rocks whose position in the geologic series can be most readily determined by fossils.

GENERAL TOPOGRAPHIC DIVISIONS OF NORTHERN CALIFORNIA AND OREGON.

The surface features of Northern California and Oregon may be grouped into two valleys and three mountain ranges. Concerning the extent of the Willamette and the Sacramento Valleys all agree, but the limits between the Cascade, Coast, and Sierra Nevada Ranges have not been definitively ascertained. The southern end of the Cascade Range is well defined at Mount Shasta, but the boundary between the Sierra and Coast Ranges is still a matter of discussion. For reasons hereafter given we will consider the northern end of the Sierra Nevada Range to be in the vicinity of the North Fork of Feather River, before reaching Lassen's Peak. From this point the elevation is continued for about fifty miles on the trend of the Sierras in the *Lassen's Peak volcanic ridge*, which terminates near Pitt River. All else south and west of Mount Shasta belongs to the Coast Range. There appears to be a want of appropriateness in including the ridges east of the Sacramento River, about the headwaters of the McCloud, in the Coast Range, but it is evident that they are more closely related geologically to the Trinity and Scott Mountains of the Coast Range than to any portion of the Sierra Nevada Range.

CHARACTER AND DISTRIBUTION OF THE CARBONIFEROUS LIMESTONE.

The presence of a limestone of Carboniferous age on the McCloud River was made known many years ago by Dr. J. B. Trask. Prof. J. D. Whitney discovered one of the same age near Pence's Ranch, and also one in Genesee Valley, where it is associated with strata containing Mesozoic fossils.[1] This is the only fossiliferous portion yet discovered in the paleozoic rocks of Northern California, and on this account it affords the most important means available for determining their stratigraphic relations. It is peculiar, however, in being a series of disconnected, sometimes widely separated, lenticular masses[2] of various dimensions, instead of one continuous stratum. That this is really the case is clearly shown at a number of places where it appears in the side of a cañon. In the complete section it is seen to thin out and disappear in all directions. There are many of these limestone lenses in Northern California. I have examined nearly a score of them, and in more than half a dozen new localities have discovered fossils, which have been submitted to Mr. C. D. Walcott for identification. His results are given in the following list:

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[1] Geol. Surv. of California. Geology, vol. i, p. 308.

[2] This peculiarity was noted by Prof. Whitney. *Ibid*, p. 210.

Fossils from the Carboniferous limestone of California.

Localities.	Fossils.
NORTHERN END OF SIERRA NEVADA RANGE.	
Western base of Sierra Nevada Range, Butte County.	
1 mile northeast of Pence's Ranch	Fragments of crinoidal columns.
W. Branch of North Fork of Feather River[a]	Coral, probably Zaphrentis sp.?
Cañon of Chico Creek, 16½ miles east of Chico	Fragments of crinoidal columns.
Middle portion of Sierra Nevada Range, Plumas County.	
Divide between Yellow and Mosquito Creeks, south of Humbug Valley.	Fragments of crinoidal columns; Lithostrotion Whitneyi; Lophophyllum proliferum?; Spirifera sp.?
Eastern portion of Sierra Nevada Range, Plumas County.	
1¼ miles northeast of Taylorville	Fragments of crinoidal columns; Bryozoans; Athyris subtilita.
1½ miles east of Hossellkus', Genesee Valley	Fragments of crinoidal columns; Athyris or Terebratula; Bellerophon sp.?
BETWEEN LASSEN'S PEAK, VOLCANIC RANGE, AND MOUNT SHASTA.	
Cedar Creek, between Buzzards' Roost and Furnaceville, Shasta County.	Fragments of crinoidal columns; Diphyphyllum sp.?; Spirifera sp.?; Spiriferina cristata; Terebratula sp.?
Northeastern base of Grizzly Peak, Siskiyou County.	Fusulina cylindrica; Productus semireticulatus; Productus cora; Athyris royssi.

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[a] Professor Whitney reports other fossils from the same region. Geol. Surv. of Cal. Geology, vol. , p. 210.

Besides the fossils enumerated in the above list, a few were collected at other localities, but unfortunately these were lost before reaching the hands of a paleontologist. Along Soda Creek, a few miles northeast of Lower Soda Springs, near the boundary between Shasta and Siskiyou Counties, a fossiliferous limestone contains many branching and cylindrical forms very like the Fusilina in the limestone near Grizzly Peak. A most important outcrop of fossiliferous limestone occurs in the Coast Range, west of Shasta Valley, along Willow Creek, near Gazelle (Edsons'). At this locality, among other fossils, was found an excellent specimen of *Lithostrotion*, and I think there can be no doubt concerning the geological age of the strata in which it occurs.

As is well known, there are many outcrops of limestone in the Sierra Nevada Range and northern portion of California, and every opportunity was embraced to examine them for fossils in order to determine their geological relations. In many places the rock is so metamorphosed as to obliterate all traces of organic remains, but there is good reason to hope that fossils will yet be discovered in new localities. Fortunately, the localities at which fossils have already been found are widely distributed in the central and eastern portion of the Coast Range as well as in the Sierra Nevada. In answer to my inquiries Mr. Walcott replies:

> As far as I can determine from the specimens submitted, there is no reason to suppose the existence of any other than the Carboniferous horizon, although the limestone at Cedar Creek is probably low in the formation.

The evidence thus far adduced all points in the same direction, and gives strong support to the proposition that all the limestone among the metamorphic rocks of Northern California is of Carboniferous age.[1]

STRUCTURE OF THE SIERRA NEVADA RANGE.

The Sierra Nevada Range at its northern end has a width of about 80 miles, extending from the Sacramento Valley to Honey Lake. It has three distinct crests, which are characterized by long, gentle slopes to the southwestward and short abrupt ones in the opposite direction.

The western crest, to which Claremont Hill belongs, is near the middle of the range and attains an altitude of about 7,000 feet. From this point the long, gentle slope extends to the Sacramento Valley at an elevation less than 300 feet above the sea. It is more or less undulating and deeply cañoned by numerous streams. From Claremont Hill the slope is abrupt towards American Valley, which at Quincy has an altitude of 3,375 feet. Continuing to the eastward the slope again rises more gently to 7,300 feet, the middle crest, in which Hough's Mountain is a prominent feature, and then descends steeply to Indian Valley at an elevation of about 3,500 feet. Further on the topography is irregular, but becomes an even slope, rising to 6,000 feet in the summit of the eastern crest, the bold escarpment overlooking Honey Lake. The outline of the Sierra Nevada Range, as seen in cross-section, is such as to at once suggest that, like the Basin Province,[2] it is composed of tilted orographic blocks, which are separated from one another by faults. The fact that Indian Valley and American Valley, which are the depressions between the crests of the range, were occupied by lakes during the Quaternary or later times greatly heightens the analogy; but to either establish or disprove the hypothesis suggested by the topography it is necessary to examine the stratigraphy of the several masses. For convenience in this discussion, the three blocks will be designated western, middle, and eastern, respectively, according to geographical position.

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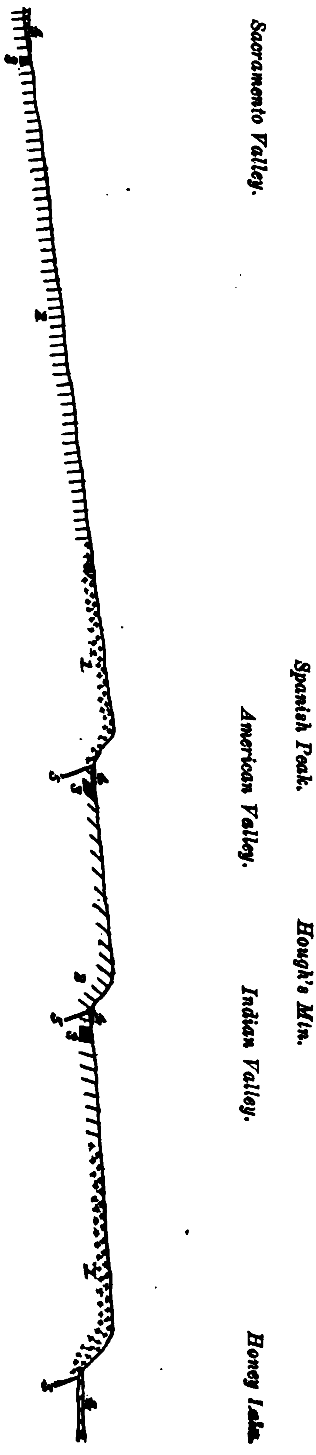
[1] Prof. J. D. Whitney, many years ago, thought it probable that all the limestone of the Sierra Nevada Range is of the same (Carboniferous) age. Geol. Surv. Cal. Geology, vol. i, p. 328; also, Aurif. Gravels, p. 41.

As far as I am aware the only limestones in California which are not of Carboniferous age are the Quaternary calcareous tufas of the Great Basin and one of the Knoxville beds, referred to by Mr. Becker in his Notes on the Stratigraphy of California. U. S. Geol. Surv. Bull. No. 19, p. 9.

[2] Geol. of the Uinta Mts., by J. W. Powell, p. 7.

The older strata, of which the range is in large part composed, are highly inclined and considerably metamorphosed. Near the western base of the mountain, as far as I have observed, the slates and limestones are usually inclined at an angle greater than 65° to the eastward, *i. e.*, towards the mass of the range, and if we accept without qualification their present order of superposition as the order of age, we should be obliged to admit that from the western base towards the middle of the range the strata are successively newer. There are good reasons, however, for supposing that instead of being newer they are either of approximately the same age or older, and that their present position is due to an overthrow. The only fossiliferous strata which have been recognized among the metamorphic rocks in the north end of the western block occur near its western base in the cañon of Chico Creek, along West Branch, and at Pence's Ranch, where the highly tilted limestone beds contain small crinoid stems and other fossils of Carboniferous age. It is a significant fact that a large portion of the auriferous slates lie east of the known outcrops of Carboniferous limestone. The broad belt of metamorphic strata upon the western slope of Claremont Hill is succeeded to the eastward by a mass of granite, which forms the western crest of the range.



GENERALIZED SECTION ACROSS NORTHERN END OF THE SIERRA NEVADA RANGE.

1.—Granite. 2.—Auriferous Slates. 3.—Carboniferous Limestone. 4.—Quaternary, or recent deposits. 5.—Faults.

If now we pass over the middle block of the range to the eastern one, which, lying between Indian Valley and Honey Lake, culminates in Thompson's Peak, we shall find a corresponding arrangement. The lower western portion of the block is made up of highly tilted strata, among which occur the limestones, shale, and sandstone containing fossils of the Carboniferous and Mesozoic ages.[1] To the eastward is exposed a mass of stratified old volcanic tufas, highly metamorphosed, and succeeded by granite, which forms the greater portion of the block. The inclination of the strata, although variable in degree and direction, is generally westward at a high angle, and in this respect differs from the position of the strata in the western block.

The middle block, lying between American and Indian Valleys and culminating in Hough's Mountain, is narrower and the strata are less disturbed than anywhere else in the northern portion of the range. The bold escarpment which faces Indian Valley exposes several thousand feet of apparently conformable slates, the position of which is very uniform for that region. Their strike is parallel to the face of the escarpment, and the dip generally less than 50° to the westward, plunging beneath American Valley. Near the western foot of the middle block in American Valley a limestone occurs which has been used quite extensively for lime. Unfortunately, I have not had an opportunity to examine this locality for fossils, but from the facts that it occurs near the suppressed western limit of the block, as does the known Carboniferous of the other two blocks, and is approximately on the strike of a limestone which outcrops further northward and contains *Lithostrotion* with other Carboniferous fossils, it appears to be highly probable that it also is of the same age.

The recurrence of the same fossiliferous strata in a cross-section of the Sierra Nevada Range in exactly analogous topographic and stratigraphic positions confirms the hypothesis suggested by its profile, that the northern end of the Sierra Nevada Range is made up of three orographic blocks separated from one another and from those of the Great Basin by profound faults, and shows that the Basin Range structure extends as far west as the Sacramento Valley. Mr. G. K. Gilbert[2] several years ago pointed out the characteristic features in the structure of the Sierra Nevada Range,[3] although Prof. Joseph Le Conte[4] had previously called attention to a profound fault along its eastern base in the vicinity of Owen's Lake. By far the greater portion of the range appears to be formed of one great orographic block, which is continuous with the western block of the range at its northern termination. Its long gentle slope westward is expressed in the drainage lines, and its eastern crest is the divide between the Great Basin and the Pacific. Almost throughout its whole extent, the Sierra Nevada faults are impassable to important streams, but at the northern end of the range, where the number of fault blocks is increased, the forks of Feather River cross two of the lines of great displacement. These streams, like nearly all of those that flow down the western slope, are in deep cañons. That of the North Fork of Feather River where it crosses the western fault has a depth of 4,000 feet, affording an excellent section of the folded strata, and its terraces indicate the character of the uplifting in forming the mountain range.

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[1] This locality was first noted by Prof. J. D. Whitney. Geological Survey of California, vol. i, pp. 308, 309.

[2] Science, March 23, 1883, p. 195.

[3] Maj. J. W. Powell and Capt. C. E. Dutton had independently arrived at essentially the same conclusion as Mr. Gilbert.

[4] Am. Jour. Sci., vol. xvi, p. 101.

Structurally the Sierra is like the Great Basin Range, differing chiefly in the magnitude and in the present elevation of the blocks. Like the orographic blocks of the Great Basin area, they are composed of plicated strata, the folding of which, as has been pointed out by a number of observers, took place long before the faulting that gave birth to the peculiar features of the ranges. It is important to remember the fact that at the time the strata of which the Sierra Nevada Range is composed were folded, *i. e.*, about the limits between the Jurassic and Cretaceous periods, the Sierra Nevada Range was not differentiated from the continental mass of the Great Basin region, and it was not until a very much later period that this separation occurred.

AGE OF THE FAULTING OF THE SIERRA NEVADA RANGE.

The age of the faulting which originated the Sierra Nevada as a distinct range has not yet been definitely determined, but the recency of the dislocations can scarcely be questioned. This is clearly shown by the fact that the amount of erosion upon the fault escarpments has been very slight. As in the Great Basin, the faults in the northern portion of the Sierra Nevada Range have given rise to lakes upon the depressed border of the blocks, but whether these lakes existed during the Quaternary period or are more recent has not yet been ascertained. At the present time the lakes have entirely disappeared, and their beds are the most fertile lands of the whole region. That the displacements are comparatively recent is indicated also by their relation to the lavas. It appears that the dislocations along the eastern side of the two lateral blocks of the range have extended into the lavas of the great volcanic field about Lassen's Peak, and if the age of the fractured lavas can be determined the period of the Sierra displacements can be more nearly ascertained. While it is possible that the faulting may have continued through a long period, it is evident that most of the movement occurred since the great volcanic effusions in that region. According to Profs. J. D. Whitney[1] and Joseph Le Conte[2] these took place among the closing events of the Pliocene[1] or the beginning of the Quaternary, and as far as my observations have extended I have no reason to differ materially from this conclusion. The faulting of the Sierra probably commenced about that time, and, if we may accept small earthquakes as evidence, it is still in progress.[2]

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[1] Amer. Jour. Sci., Sept., 1864; also, Auriferous Gravels, p. 74.

[2] Amer. Jour. Sci., vol. xix, p. 188.

AGE OF THE AURIFEROUS SLATES.

There is considerable difference of opinion concerning the age of the auriferous slates, but there is no good reason whatever for dissenting from the view generally accepted that at least a portion of the auriferous slates are Mesozoic. The fact that the Carboniferous limestone is intimately associated with the gold-bearing slates about the northern end of the Sierra Nevada Range suggests that a portion of these may belong to Paleozoic or older formations.[1] The lenticular character of the limestone and the complex plications of the strata among which it occurs render it very difficult to determine in most cases, without fossils, whether the slates are above or below the limestone. I have already suggested that it appears to be a somewhat significant fact that a large portion of the auriferous slates lie east of the known outcrops of the Carboniferous limestone near the western base of the range. The folding of the strata brought them at many places into an approximately vertical position. At the time of the subsequent faulting the eastern edge of the largest block was so elevated as to make the strata which were formerly vertical dip steeply to the eastward, and in this manner strata upon the western slope of the Sierra Nevada Range may have been made to overlie more recent ones nearer its base. This explanation is suggested simply to show that the present eastern inclination of the strata upon the western slope of the range does not militate against the view that a portion of the auriferous slates are more ancient than the Carboniferous limestone.

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[1] In the neighborhood of Pence's Ranch the auriferous gravels are distinctly overlaid by stratified deposits which Professor Whitney regarded as Upper Pliocene (Geol. Surv. of Cal., vol. i, p. 211). A few imperfect leaf impressions were collected from these strata and submitted to Prof. L. F. Ward for examination. One of the specimens has been doubtfully determined as Cinnamomum or Paliurus, and Professor Ward remarks, "If it were certain that the specimen is either Cinnamomum or Paliurus, I should say that it could scarcely have come from a higher horizon than the Miocene and more likely from a lower. But the specimen may possibly represent a Populus unlike any modern form. At any rate I would not have been surprised at just such a collection from the Eocene or Laramie Group." That the strata containing the leaf impressions overlie the auriferous gravels at the Cherokee mine near Pence's Ranch there can be no question. Professor Whitney showed that the auriferous gravels probably represent the whole of the Tertiary (Aurif. Gravels, p. 283), and may it not be possible that the old stream bed of the Cherokee mine is Eocene or Miocene? In the same vicinity the Tertiary strata overlie the rocks of the Chico Group, and the two series of strata are almost, if not altogether, conformable. Dr. C. A. White, who visited the region lately, is of the impression that the strata referred to are not older than the Upper Pliocene. All that can be definitely stated at present concerning the strata containing the leaf impressions is that they are more recent than strata known to belong to the Chico Group, and that their flora, as far as Professor Ward can judge from the few imperfect specimens at hand, has a pre-Pliocene aspect. The great volcanic outburst in the vicinity of Lassen's Peak succeeded the deposition of these strata of questionable age, probably occurring, as stated above, about the close of the Pliocene.

[2] Small earthquake shocks are frequently felt about the northern end of the Sierra Nevada Range, especially in the vicinity of the fault scarps. Prof. Joseph Le Conte (Am. Jour. Sci., vol. xvi, p. 101) regarded the Inyo earthquake in 1872 as almost certainly due to a slight readjustment along the eastern fault of the Sierra near Owen's Lake. Some unpublished observations by I. C. Russell and W J McGee show that there has been actual post-Quaternary displacement near the eastern base of the Sierra.

There is evidence of a slight post-Quaternary elevation of the Lassen's Peak volcanic ridge along an interesting monoclinal fold which marks the limit between the Piedmont region of the range and the Sacramento Valley, a few miles east of Red Bluff. The displacement is less than a hundred feet and the latest yet discovered in that region, but does not properly belong to movements of the Sierra Nevada Range, as the fold runs out to the southward before reaching the limit of the volcanic tufas.

Mr. Clarence King[2] called attention to the great thickness of Paleozoic littoral deposits of the Great Basin region and inferred the existence of a large land mass further westward from which these sediments were derived. Prof. Joseph Le Conte has argued that upon the marginal sea-bottom bordering the western shore of this ancient Paleozoic and Mesozoic land were laid down a great accumulation of sediments, out of which the Sierra Nevada Range has been formed.[3] It was, therefore, with great interest that I examined the eastern escarpments of the great fault-blocks of the Sierra Nevada Range, in the hope of being able to demonstrate the presence or absence of a considerable thickness of strata older than the Carboniferous limestone.[4] The stratified rocks of the eastern and western blocks of the Sierra Nevada Range are highly contorted, and the eastern escarpments are formed of granite, but in the middle block, lying between American and Indian Valleys, the strata, although tilted, are not so profoundly plicated. The bold escarpment facing Indian Valley, as has already been stated, exposes thousands of feet of apparently conformable auriferous slates which dip steeply westward beneath the supposed Carboniferous limestone of American Valley. These strata are so slightly metamorphosed as to encourage the hope of finding fossils in them, and I was greatly disappointed in having to give up a brief but fruitless search. Nevertheless, the stratigraphic relations are such as to render it very probable that at this point there is a great thickness of Paleozoic strata exposed and that a large part of the gold-bearing slates are older than the Carboniferous limestone.[1]

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[1] Note sur la Géologie de la Californie, par M. Jules Marcou. Bull. de la Soc. géol. de France, 3^{me} s., tome xi, p. 407.

[2] Geol. Exp. of the Fortieth Parallel. Syst. Geol., vol. i, p. 534.

[3] Am. Jour. Sci., III, vol. iv, p. 460, and vol. xvi, p. 103.

[4] Professor Whitney remarks that the age of the bed rock series can be set down with certainty as being nowhere more recent than Jurassic, and that it is not impossible but quite improbable that any portion of the metamorphic belt of the Sierra may prove to be older than the Carboniferous (Aurif. Gravels, p. 314). Mr. George F. Becker noted sandstones below and probably older than the Carboniferous limestone of the McCloud River (U. S. Geol. Surv. Bull. 19, p. 21).

GENERAL DISTRIBUTION OF THE METAMORPHIC, VOLCANIC, AND CRETACEOUS ROCKS.

There are in Northern California two large areas of metamorphosed Mesozoic and Paleozoic rocks. The one occupies the northwestern corner of the State, entering from Oregon and extending as far southeast as Pitt River; this area is insular in its relation to later formations. The other is of continental dimensions, stretching into California from Nevada, and embraces the whole region of the Sierra Nevada Range. The great faults of this range run out in the vicinity of the North Fork of Feather River, apparently vanishing through short monoclinal folds where the platform of ancient metamorphic rocks is gradually depressed northwesterly, and disappears beneath the lavas of the great volcanic field. Continuing in the same direction, these rocks reappear upon the surface near Pitt River, and form the insular area to which reference has already been made. Concerning the depth of the depression in the metamorphic rocks between the two areas now exposed we have but little knowledge; however, there is no reason as far as I am aware for supposing it to be very great.

Following the trend of the Sierra Nevada Range northward from the North Fork of Feather River to Pitt River we find a volcanic ridge made up of numerous adjoining cones, among which Lassen's Peak is most prominent. This ridge has been designated Lassen's Peak volcanic ridge, and is composed almost exclusively of accumulated lavas rising to an average elevation of over 5,000 feet, with several peaks above 8,000 feet in altitude. The numerous craters of various magnitudes are irregularly distributed, and no definite relation to the lines of great displacement in the Sierra Nevada Range is apparent. In fact, as has already been shown, the great faulting occurred towards the close of the period of greatest volcanic activity. To the north and northeastward of this volcanic range the recent lavas stretch far into Oregon, Idaho, and Washington Territory.

Mr. Becker and others have called attention to the great unconformity between the rocks of the Chico Group and those upon which they rest. The geography of our western coast during the deposition and plication of the older strata is a matter concerning which we have as yet but little knowledge. Its development is first distinctly outlined in the rocks of the Chico epoch. These rocks are generally fossiliferous, and their identification is a matter of no great difficulty. They are exposed at many points along the western base of the northern portion of the Sierras, and are either horizontal or dip away from the mountain at a very low angle. In the latitude of Oroville the rocks of this group rise to an elevation of 800 feet above the sea. Further northward, along Chico Creek, they reach 1,700 feet, and continuing in the same direction the elevation becomes greater. Two miles east of Montgomery Creek, on the road from Redding to Burney Valley, they have an elevation of over 2,400 feet. At this point they are coarse deposits, evidently formed near a shore which lay a short distance to the northwest in the vicinity of Pitt River. They dip eastward, disappearing beneath the Lassen's Peak volcanic ridge, and very probably connect beneath the great lava fields with the rocks of the same age in Shasta Valley and Crooked River in Oregon east of the Cascade Range.[1] In the northwest part of Shasta Valley, besides the fossiliferous sandstone, there are coarse shore deposits of the same age clinging upon the sides of the Scott Mountains and reaching far up towards their summits. The distribution of the rocks of the Chico Group clearly indicates that during the Chico epoch the northwestern portion of California, with the adjacent part of Oregon, embracing the Trinity, Salmon, Scott, Siskiyou, and other mountain ridges of the Coast Range, was a large island, separated from the still larger continental land mass of the same strata in the Great Basin and Sierra region by a wide strait now bridged over by the Lassen's Peak volcanic ridge.

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[1] Professor Whitney refers to the fossils found in Genesee Valley in demonstrating that a large part of the auriferous slates are Mesozoic (Aurif. Grav., p. 309). These slates in Hough's Mountain ridge, upon the southwestern side of Indian Valley, are regarded by miners as the "home of the mother ledge" of that country, and being apparently older than the Mesozoic strata containing the fossils are separated from them by a profound displacement.

Dr. White asserts that the auriferous slate series is known to include strata of Carboniferous age and some that are apparently older. Notes on the Mesozoic and Cenozoic Paleontology of California, U. S. G. S. Bull. No. 15, p. 25.

RELATION OF THE SIERRA, COAST, AND CASCADE RANGES.

The geography of the western coast during the Chico epoch enables us to define sharply the limits between the Sierra Nevada and the Coast Ranges. The former has been from its inception joined to the continental land, while the latter embraces all the ridges developed out of the cretacean island, and the Lassen's Peak volcanic ridge separates them. Both ranges contain plicated Paleozoic as well as Mesozoic strata. The Coast Range received large tertiary additions not represented in the Sierras, but, on the other hand, the latter was differentiated from a continental mass by the development of a peculiar structure not yet recognized in the Coast Range. The relation between the Coast and the Cascade Ranges is not so sharply defined, but when we consider their widely diverse modes of origin their limitation is not a matter of so great difficulty. South of the Rogue River Valley the cretacean island lay completely west of the position now occupied by the Cascade Range. To the northward its extension is but partially known. Near the summit of the Cascade Range, upon its western slope, about half a dozen miles from Mount Hood, is a large mass of coarsely crystalline eruptive rock, closely related to the gabbros. A similar rock occurs near the western base of the range, 8 miles east of Lebanon, and Mr. Becker[1] has said that east of Roseberg granite and metamorphic rocks occur about the headwaters of the Umpqua. Such rocks make up the Coast Range west of Mount Shasta, and it may be that they form an elevated foundation for a considerable portion of the Cascade Range between the headwaters of Rogue River and Mount Hood, but this is rendered less probable by the complete section along the Columbia River, where the range is cut across nearly to the sea level, showing, according to Le Conte,[2] that it is composed almost wholly of modern lavas resting upon undisturbed strata of Miocene age. The excellent section of the southern portion of the range afforded by the Klamath River shows, at least as far as I have observed, that it is made up at that point[3] completely of recent eruptive rocks.

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[1] Mr. Eugene Ricksecker, a topographer of the Geological Survey, informs me that he observed a number of fossils where a well had been recently dug a short distance north of Rhett Lake, Oregon, and it is possible that the locality may afford fossils of the Chico group.

Between the Siskiyou Mountains and the Cascade Range, in Southern Oregon, as Whitney has shown,[4] the Cretaceous strata of the narrow belt are highly tilted. They dip eastward beneath that portion of the Cascade Range, as do those of Shasta Valley as well, and probably connect with the rocks of the same age east of the Cascade Range. The apparently complete absence of older rocks in the Klamath River cañon through the Cascade Range and the relation of the Cretaceous strata on both sides of the range indicate clearly that the region now occupied by the southern portion of the Cascade Range was beneath the sea during the Chico epoch. As far as is definitely known the Cascade Range was not represented by a ridge of older metamorphic rocks which were folded and upheaved at the same time with the Sierra and older portion of the Coast Range, and is entirely distinct from them in structure and origin. On the contrary, however, the region occupied by it as well as the short range north of Lassen's Peak are but parts of the great volcanic field that occupies the area which during the Chico epoch was one of depression between the island and the continent.[5]

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[1] U. S. Geol. Surv. Bull. No. 19, p. 20.

[2] Amer. Jour. Sci., III, vol. vii, pp. 167, 259.

[3] Two miles below Shovel Creek, on the left bank of the Klamath River, by the road from Yreka, Cal., to Linkville, Oreg., in a ledge of gray rock which in the field I regarded as one of the metamorphic slates, but under the microscope it is seen to be a lava.

[4] Geol. Surv. of Cal., vol. i, page 354.

[5] See Dr. White's remarks, "Notes on the Mesozoic and Cenozoic Paleontology of California," U. S. G. S. Bull. No. 15, p. 31.

CONCLUSIONS.

The points to which it is desired to call especial attention may be briefly summarized as follows:

It appears that all the limestone among the metamorphic rocks of the Coast and Sierra Nevada Ranges is of Carboniferous age.

The northern portion of the Sierra Nevada Range, like that of the Great Basin, is composed of tilted orographic blocks separated from one another by great faults.

The greater portion of the range is formed by one of these blocks, with a short abrupt slope towards the Great Basin and a long gentle slope in the opposite direction.

The displacements by which the Sierra Nevada Range was separated from the Great Basin land mass probably began about the close of the Tertiary, and may be yet in progress.

A large portion of the auriferous slate series is apparently older than the Carboniferous limestone.

During the Chico epoch a large part of the region now occupied by the Coast Range was an island separated by a wide strait from the continental mass to which the Sierra Nevada Range belonged, which strait has since been filled by the lavas of the Lassen's Peak volcanic ridge.

As far as is definitely known, the Cascade Range was not represented by a ridge of metamorphic rocks corresponding to the Sierra and Coast Ranges, but belongs rather to the great volcanic field which now occupies the area once depressed between the cretacean island and the continent.

ADDENDUM.

While completing the survey of the Lassen's Peak volcanic belt during the field season of 1886, much additional evidence was obtained supporting the views expressed in this paper. Geologically considered, Lassen's Peak belongs to the Cascade Range, and several of the foregoing assertions should be somewhat extended.

Mr. Walcott has examined a few fossils from Willow Creek, a locality referred to on page 11. He identified the following forms: Lithostrotion mamillare, Terebratula, Pleurotomaria, Orthoceras, Zaphrentis, Favosites, and crinoidal columns.

Some fossils recently collected near Rhett Lake do not belong to the Chico group but to a much later horizon.

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NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume V.

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No. 34

ON THE RELATION OF THE LARAMIE MOLLUSCAN FAUNA TO THAT OF THE SUCCEEDING FRESH-WATER EOCENE AND OTHER GROUPS.

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79a

ON THE RELATION
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RELATION OF THE LARAMIE MOLLUSCAN AND FRESH-WATER EOCENE FAUNAS.

BY CHARLES A. WHITE, M. D.

GENERAL REMARKS.

Certain equivalent strata which are found exposed at various and widely separated localities in Utah and Southern Wyoming containing fresh-water types only among their fossil molluscan forms, have for several years past been known to contain a few species which are elsewhere characteristic of the Laramie Group. At a few of the localities referred to the strata have been regarded as belonging to the Laramie Group, but generally they have been assigned to the base of the fresh-water Eocene series. No difference of opinion seems to have existed among the geologists who have observed them as to their position in the stratigraphical series. They seem to have differed only in regard to the position of a plane of demarkation which should separate them from the unmistakable Laramie strata beneath. The strata which are found exposed at the following-named localities are especially referred to in the following remarks: The vicinity of the town of Wales, the valley of Twelve Mile Creek east of Mayfield, the west base of Musinia Mountain—all in the large county of San Pete, Utah; Soldier's Fork, Utah County, Utah; Desolation Cañon of Green River, Eastern Utah; and near Evanston, Southwestern Wyoming. Besides these, certain localities near Panguitch and Upper Kanab, respectively, in Southern Utah, ought also to be mentioned.

Not having had until the past season a satisfactory opportunity to study the strata at any of the localities just mentioned, I have heretofore regarded them as belonging to the upper part of the Laramie Group, because of the presence in them of the Laramie species referred to. Investigations in Utah during the past season, together with a further study of the collections which were previously made in that region by different parties of the Government surveys, have satisfied me that the strata of the localities which have just been named, although they contain those Laramie species, are all equivalent portions of the Wasatch Group, the lowest group of the purely fresh-water Eocene series.

In the prosecution of my field studies during the past season more especial attention was given to the strata which were found exposed in San Pete Valley and the adjacent portion of the Wasatch Mountains. My principal collections of Wasatch fossils were also made from these strata, mainly near the town of Wales, in the hills which form the western side of San Pete Valley. In that vicinity these hills are composed from base to summit of strata of the Wasatch Group, which there reach an estimated thickness of about 2,500 feet. These strata consist of sandstones, shales, marlites, and a few layers of impure limestone, resting upon a very coarse conglomerate which forms the base of the hills, all evidently forming one uninterrupted series from bottom to top.[1]

The base of the Wasatch Group was not recognized at this locality, but it is probably not much beneath the surface of the valley here. Some two or three hundred feet above the conglomerate there is a bed of coal, which has been worked at several points, the openings being known as the Wales Coal Mines. The fossils which were collected from these strata were found at different horizons, ranging from about 100 feet beneath the coal to the top of the hills, the vertical range of the fossil-bearing strata being more than 1,500 feet. I have recognized 26 species of invertebrate fossils which were obtained here, all plainly belonging to one and the same fauna, and in a layer immediately above the coal some undetermined vertebrate remains were found.

Some of these invertebrate forms are common in the Wasatch Group elsewhere; three or four of them are known to occur also in the Green River Group; some of them are characteristic Laramie species, and some of them are new. A part of them have also been found at the Almy Coal Mines, near Evanston, Wyo., and a part were found by Major Powell in Desolation Cañon; others at localities in Southern Utah and at the west base of Musinia Mountain; a part were found by Mr. E. E. Howell at Twelve Mile Creek, and one of them is apparently identical with a form which Professor Cope obtained from his Puerco Group in New Mexico.

The equivalents of the strata which are exposed near the town of Wales are also largely exposed in the Wasatch Mountains upon the east side of San Pete Valley, and, as is mentioned further on, those strata are there found to rest conformably upon the Laramie. It is worthy of note in this connection that the Laramie strata upon which these fresh-water Eocene strata rest are referable to the Laramie proper, and not to the strata known as the Bear River Laramie, upon which the Wasatch apparently lies unconformably in the vicinity of Evanston.[1]

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[1] This conglomerate is probably a part of the great Wasatch conglomerate which is so largely exposed in the valley of Weber River, in Echo Cañon, and elsewhere in Southern Utah.

The following is a list of the species which were collected at the Wales locality. They are tabulated so as to show in part the localities and the different horizons at which they have been recognized. Those species which are indicated in the table as ranging from the Laramie into the Wasatch Group have been found mainly in the lower portion of the latter group, but some of them range more than 500 feet above the coal at the Wales locality, which is more than 1,000 feet above the base of the group. Furthermore, a small number of the species found in the Wasatch strata at the Wales locality are known to range into the Green River Group, and one at least into the Bridger Group. To this list is added the Helix and the Pupa which were obtained by Professor Cope from his Puerco Group in New Mexico. Some of the names in this list are now regarded as synonyms, as will appear from remarks in connection with the description of species on following pages.

Table showing range of species.

List of fossils.	Wasatch.							Puerco Group.	Typical Laramie.	Green River Group.	Bridger Group.
	Wales, Utah.	Twelve-Mile Creek.	Musinia Mountain.	Soldier's Fork.	Southern Utah.	Evanston.	Desolation Cañon.				
Unio mendax White	×			×			×				
Unio rectoides, n. s	×							×?			
Sphærium formosum Meek & Hayden.	×					×?			×		
Limnæa ——?	×										
Limnæa (Leptolimnæa) minuscula White.	×									×	
Acella micronema, n. s	×									×?	
Planorbis convolutus Meek & Hayden.	×								×		

---

[1] There is now some reason to doubt whether the strata which have hitherto been known as the Bear River Laramie should be regarded as a portion of the Laramie Group. That their position is between the uppermost of the marine Cretaceous groups and the basal portion of the Wasatch, as is that of the Laramie proper, is apparently beyond question, but so far as is now known not a single fossil species is common to both the Bear River strata and the Laramie proper. It seems therefore necessary to infer that the fauna of the former strata lived in a separate body of water; but whether it preceded, followed, or was contemporary with the Laramie cannot be asserted now with confidence. The question is rendered still more obscure by the fact that the Bear River fauna contains types which are not known in any other North American strata, nor among living faunas of this continent. In these discussions reference is made to the fauna of the Laramie proper, and not to that of the Bear River Laramie

Table showing range of species—Continued.

List of fossils.	Wasatch.										
	Wales, Utah.	Twelve-Mile Creek.	Masinis Mountain.	Soldier's Fork.	Southern Utah.	Evanston.	Desolation Cañon.	Puerco Group.	Typical Laramie.	Green River Group.	Bridger Group.
Planorbis (Gyraulus) militaris White.	×	......	......	......	......	......	......	......	......	×	......
Physa pleromatis White	×	......	......	......	......	......	......	......	......	×	......
Physa bullatula, n. s	×	......	......	......	......	......	......	......	......	......	......
Physa kanabensis White	×?	......	......	......	×	......	......	......	......	......	......
Bulinus atavus White	×	......	......	......	......	......	......	......	......	......	......
Acroloxus actinophorus, n. s	×	......	......	......	......	......	......	......	×?	......	......
Helix nacimientensis, n. s	......	......	......	......	......	......	......	×	......	......	......
Helix adapis, n. s	......	......	......	......	......	......	......	×	......	......	......
Pupa leidyi Meek	......	......	......	......	......	......	......	×?	......	......	×
Goniobasis tenuicarinata Meek & Hayden.	×	......	......	......	......	......	......	......	×	......	......
Goniobasis nebrascensis Meek & Hayden.	×	×	......	......	......	×	×	......	×	......	......
Goniobasis filifera, n. s	×	......	......	......	......	......	......	......	......	......	......
Goniobasis tenera Hall	×	......	......	......	......	......	......	......	......	×	×
Hydrobia recta White	×	......	......	......	......	×	......	......	......	......	......
Hydrobia utahensis White	×	×	......	......	......	......	......	......	......	......	......
Micropyrgus minutulus Meek	×	......	......	......	......	......	......	......	×	......	......
Viviparus trochiformis Meek & Hayden.	×	×	×	×	......	......	×	......	×	......	......
Viviparus leidyi Meek & Hayden.	×	×	×	×	......	......	×	......	×	......	......
Viviparus raynoldsianus Meek & Hayden.	×	......	......	......	......	......	......	......	×	......	......
Viviparus panguitchensis White.	×	×	×	×	×	......	×	......	......	......	......
Viviparus nanus, n. s	×	......	......	......	......	......	......	......	......	......	......
Cypris sanpetensis, n. s	×	......	......	......	......	......	......	......	......	......	......

The following general remarks are presented in this connection for the purpose of explaining the relation which the Wasatch Group, as it is developed in Utah, is understood to hold to the Laramie and other groups. The intimate stratigraphical relation of the Laramie Group to the marine Cretaceous series beneath it has been recognized by every field geologist who has studied those strata, and it is this fact, in addition to the discovery of dinosaurian remains in the Laramie, that has led them to range that group as a member of the Cretaceous series. While there seems to be no reason to doubt that sedimentation was continuous, not only through the marine Cretaceous series, but also from that series into and through the Laramie, it is true that there was at the beginning of the Laramie period a comparatively sudden change in the character of the previously existing molluscan fauna over the whole area which was then occupied by the Laramie waters; that is, at a certain horizon in the unbroken succession of strata there is an abrupt disappearance of all distinctively marine forms,[1] and an equally abrupt accession of brackish water and fresh water forms which continue through the whole Laramie Group.

On the other hand similar evidence of continuous sedimentation from the Laramie into the Wasatch Group has not hitherto been publicly announced. It is true that a conformity of the Wasatch upon the Laramie in some places has been distinctly recognized by Major Powell[2] and myself, but others have denied the existence of any such conformity.[3] Wherever later strata have been discovered resting upon those of the Laramie Group, as its limits are indicated in note 2, below, they have been found to be free from all fossil forms which can be reasonably referred to even a slightly saline habitat, while the Laramie strata contain many brackish water forms throughout their vertical range.

That is, those overlying strata contain such genera of fresh-water and land mollusca as characterize existing lakes and rivers and the land adjacent to them. In my former writings upon the Laramie Group I have suggested that its whole molluscan fauna ceased abruptly with the close of that period, for I did not then know that any of the numerous fresh water species of the Laramie Group survived their brackish-water contemporaries and became members of the Wasatch fauna. I thought it probable that the physical changes which attended the extinction of the brackish-water mollusca of the Laramie sea were also attended by a like extinction of their fresh-water contemporaries. Still, I had expressed a hope that certain of the fresh-water species would yet be found to have continued their existence into the Wasatch epoch.[1]

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[1] One species each of *Nuculana*, *Axinæa*, and *Odontobasis* appears to have survived the partial freshening of the Laramie waters; but this fact is not regarded as affecting the general statement that true marine conditions ceased at the beginning of the Laramie period.

[2] Reference is here made to the Report on the Geology of the Uinta Mountains, by J. W. Powell. The plane which he then recognized as separating the Laramie (Point of Rocks Group) from the marine Cretaceous group beneath it gave certain layers to the Laramie which contain fossils properly belonging to the Cretaceous, but none of which fossils belong to the true Laramie fauna, as it is now understood. He also referred certain layers containing only characteristic Laramie forms to the base of the Wasatch (Bitter Creek Group). In these views I then concurred, as will appear by referring to Chapter III of the report cited, but I have since regarded the Laramie as beginning where the distinctively marine forms cease and ending where the brackish water forms cease. It will thus be seen that the unconformity which we referred to (*loc. cit.*) as existing between the Laramie and the Wasatch groups really occurs within the Laramie. For my observations on the conformity of the Wasatch upon the Laramie, see Tenth Annual Report of the United States Geological and Geographical Survey of the Territories, page 33; Eleventh Report, pages 210 and 223; and Twelfth Report, Part I, page 53.

[3] See report of the Geological Survey of the Fortieth Parallel, Volume I, page 553; Volume II, page 201.

This tentative opinion not having been then confirmed by known facts, I considered the few species I had recognized among the collections from Utah and Southern Wyoming as being identical with certain forms from the Laramie strata of the Upper Missouri River region to belong to the upper part of the Laramie beds in that more southern region. This idea of a definite restriction of the upward range of all the Laramie species seemed to be supported by Professor Cope's discovery in New Mexico, in strata holding an intermediate position between well recognized Laramie strata beneath and equally well recognized Wasatch strata above, of a vertebrate fauna which is distinctly different from that of either of those groups. According to Professor Cope,[2] so different is this vertebrate fauna from the faunas which preceded and those which followed it that he has separated the strata containing it as a distinct group under the name of the Puerco Group. At the typical localities of this group in New Mexico and Southern Colorado he recognizes the strata containing the Puerco fauna as having distinguishing stratigraphical characteristics. Dr. F. M. Endlich[3] and Mr. W. H. Holmes[4] also recognized that distinction in Southern Colorado; but in other places at which the Laramie and the Wasatch have been studied in juxtaposition, especially in Utah and Southern Wyoming, the Puerco Group has not hitherto been recognized either by stratigraphical or by paleontological characteristics. Professor Cope gives the maximum thickness of the Puerco beds in New Mexico as about 850 feet. With this estimate Mr. Holmes essentially agrees, but Dr. Endlich estimates their thickness at something more than this in Southern Colorado. All three of these authors agree, however, that the Puerco beds are conformable with the Laramie beneath and with the Wasatch above; and they all, when those beds were first discovered, regarded them as a part of the Wasatch Group.

As has been already intimated, it is now known that within an area which comprises a large part of the Territory of Utah not only is there a true conformity of the Wasatch upon the Laramie, but several of the characteristic molluscan species of the Laramie Group pass up into the Wasatch strata and there become members of the purely fresh-water fauna of that group. In all the region where this intimate stratigraphical and paleontological relation of the Wasatch to the Laramie was observed the character of none of the strata of either the Laramie or the Wasatch was such as to suggest the propriety of separating them from either or both of those formations as a distinct group or even as a subordinate division. That is, I observed nothing in the character of these strata which suggested to me the presence in that region of the Puerco Group of Cope. Having received from Professor Cope a small collection of fresh-water and land shells which he obtained from typical Puerco strata near the town of Nacimiento, N. Mex., and which are figured on Plate I, special search was made for like forms in the Utah strata just referred to, but with the exception of the somewhat satisfactory identification of the Puerco *Unio* with *U. rectoides* of the Wasatch strata near the town of Wales, this search was without material success. The probabilities are that the lower portion of the Wasatch series in that part of Utah represents the Puerco Group of Cope; but because of the now known range of molluscan species from the Laramie into the Wasatch Group, the actual identification of such species alone in both the Wasatch and the Puerco would not serve to fix the Puerco horizon in the Utah region with precision. That is, the facts at present known seem plainly to indicate that while the Puerco fossils which have been published by Professor Cope indicate a distinct epoch in the history of North American vertebrate life, neither the stratigraphy nor the remains of molluscan life, so far as it is now known, give any corresponding indication of either physical or faunal changes.

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[1] Twelfth Annual Report of the United States Geological and Geographical Survey of the Territories, pp. 51 and 52.

[2] For a concise statement concerning the Puerco Group and its vertebrate fauna by Professor Cope, see American Naturalist, Volume XIX, p. 985. For important references to its vertebrate fauna by him, see the same Volume, pp. 385 and 493.

[3] Ninth Annual Report United States Geological and Geographical Survey of the Territories for 1875, p. 189.

[4] *Ibid.*, pp. 243 and 248.

For the present, therefore, while I do not hesitate to recognize the Puerco epoch as it is indicated by the vertebrate fauna which Professor Cope has published, I am not able to recognize the existence of a distinct group of strata representing that epoch in the region which I have examined; that is, I admit that a record of the Puerco epoch has been made in the history of vertebrate life, but not in that of aqueous invertebrate life, nor, except locally, in the stratigraphical series.

The species which have been found to pass from the Laramie into the Wasatch are figured and described, together with others, on following pages of this bulletin. Such a perpetuation of specific forms of gill-bearing mollusks seems to make it necessary to infer that there was an unbroken continuity of aqueous habitat and also continuous sedimentation from the Laramie to the Wasatch Group. The condition of the strata in that part of Utah which I have recently examined also favors the inference as to the continuity of sedimentation. The area within which this blending of the Laramie with the Wasatch took place, although large, is evidently much smaller than that over which the blending of the marine Cretaceous strata (not its fauna) with those of the Laramie has been observed.

The strata which indicate the intimate relation of the Laramie with the Wasatch are much disturbed in that district and the difficulty of tracing their succession is largely increased by the presence of surface débris and vegetation upon the mountain slopes. Still, this succession was traced with a good degree of satisfaction in the cañons upon the eastern face of the Wasatch Range in Emery and San Pete Counties, Utah. Beginning with the bluish marls of the Colorado Group in Castle Valley I traced the successive strata without a break, as I think, through the Fox Hills and Laramie Groups into and through the Wasatch Group. In addition to this is the well-known intimate relation of the three groups of Eocene fresh-water deposits with each other, namely, the Wasatch, the Green River, and the Bridger, especially in the Green River Basin north of the Uinta Mountains. That is to say, certain species of mollusks range through these three groups, which are everywhere conformable, and it is evident that sedimentation was continuous through the whole series.

We seem, then, to have conclusive proof that there is a complete and unbroken stratigraphical series in that western region, extending from the Middle Cretaceous to the top of the Eocene, and aggregating nearly or quite two miles in thickness. A remarkable fact connected with the production of this great series is that, while sedimentation was evidently not materially interrupted in at least a large part of the area within which those deposits are now found, the aqueous life was changed first from that of a purely marine character to that of alternating brackish and fresh waters, and finally to that of a purely fresh-water character; that is, the waters in which this series of strata were deposited were first marine, then alternating brackish and fresh, and finally wholly fresh. This, of course, implies the occurrence of great physical changes upon the North American continent during the Cretaceous and Eocene periods, which, however, did not interrupt sedimentation in a large part of its interior.

The inability of geologists to fix upon a definite plane of demarkation which shall separate the uppermost of the marine Cretaceous strata from those of the Laramie Group has been referred to and is well known. It is now also known that a similar state of things really obtains within a large part of the Territory of Utah with regard to the strata of the Laramie and the Wasatch groups; and it is not strange that strata upon the confines of each of these groups, and containing an identical fauna, should have been sometimes referred to one and sometimes to the other group before the fauna had been recognized as identical. So far from there being an abrupt faunal break between the Laramie and the Wasatch groups, as was formerly supposed, it is now known that the faunal relation between the two groups is more intimate than that between the Laramie and the marine Cretaceous, for no species are yet known to have passed from the latter up into the Laramie.

The fact of the survival into the Wasatch epoch of several fresh-water molluscan species which have hitherto been regarded as belonging exclusively to the Laramie naturally leads us to inquire whether the upper portion of the Laramie series in the Upper Missouri River region and elsewhere may not be as properly referred to the Wasatch as to the Laramie. Applying the rule for the determination of the upper limit of the Laramie Group which I have designated on a previous page, it appears probable that at least the upper portion of the series of strata which are exposed in the vicinity of Fort Union, near the mouth of Yellowstone River, should be referred to the Wasatch Group. That the lower portion of the series known as the Fort Union beds belongs to the Laramie Group cannot be doubted, because of the presence there of characteristic dinosaurian and other vertebrate remains; but there is evidently no break in that series of strata which should separate them as two formations. In the upper part of the series, however, only fresh water molluscan forms have been found, if we except one species of *Corbula*, and this is understood to have come from a comparatively low horizon. Moreover, several of the same species of mollusks which are found in the Fort Union series of Laramie strata are also found in the Wasatch strata of Utah.

This suggestion of the intimate relation of the Laramie of the Upper Missouri River region to the fresh-water Eocene series is apparently supported by the discovery of some fresh-water beds on the top of Sentinel Butte, in that region. These beds are connected with the Laramie strata beneath by direct continuity, and I have suggested that they probably represent the Green River Group.[1]

Before closing these remarks, it is thought desirable to state concisely the grounds for my conclusion that the strata in the western portion of our national domain form one uninterrupted series from the lowest of the marine Cretaceous formations to the top of the Bridger Group, the uppermost of the fresh-water Eocene series, inclusive. These reasons fall under two separate categories, the one based upon observed stratigraphical conditions and the other upon the character and distribution of the fossil contents of the respective groups of strata.

The stratigraphical conditions which indicate continuous sedimentation from one group or formation to the next succeeding one in this great series are, first, conformity, and second, absence of abrupt change in the character or composition of the material deposited. That is, although there are numerous instances of unconformity within the vertical range of the great series in question, especially above the distinctively marine Cretaceous strata, that unconformity in no case involves the whole of any formation of the series. In other words, where unconformity between any two formations, or any two portions of the same formation, is apparent at any one locality, perfect conformity is to be found at some other localities. The greatest and most complete unconformity in the great series has hitherto been understood to exist between the Laramie and the Wasatch groups; but it is now known that at even this horizon there is perfect conformity within a great area which includes a large part of the Territory of Utah. This area has doubtless been materially reduced, because the strata have been so much displaced and eroded.

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[1] American Journal of Science, third series, Vol. XXV, pp. 411–414.

The paleontological evidence of the unbroken continuity of the series of formations in question consists mainly in the known passage of certain species of fossils from one formation up into the next. That some of the species which existed in and about the estuaries of the marine waters in which the Cretaceous formations were deposited survived in the brackish waters of the Laramie sea is probable, but it has not yet been demonstrated by the specific identification of any such fossils in the Laramie strata. That certain species of molluscan fossils range through all three of the purely fresh-water Eocene Groups has long been known, and it is now also known that there is a similar range of a considerable number of fresh-water species of the Laramie period which coexisted with its brackish water forms, up into the Wasatch Group. This demonstrates the faunal continuity of the series from the base of the Laramie to the top of the Bridger Group. The passage of these fresh-water species from one group to another is understood to indicate that there must have been a continuity of congenial habitat from the one epoch to the other. If that habitat was not continuously lacustrine, the only way in which it is thought possible that any of the fresh-water species in question could have survived was by escaping into fluviatile waters from their original lacustrine habitat and returning to a similar one subsequently established on the same ground. The character of the deposits in which these fossils are found indicates that sedimentation was continuous from the Laramie to the Wasatch, and an aqueous habitat was therefore continuous from the one epoch to the other. The survival into the latter epoch of certain species which flourished in the former one shows that that habitat was continuously a congenial one to them. This conclusion, of course, implies that the individuals of those surviving species whose remains are found in the upper formation were direct lineal descendants of those in the lower. There appear to be only two alternatives to this conclusion, first, that the species have been incorrectly identified, or, second, that they were reintroduced after they had once become extinct. In the light of modern zoology the latter proposition is not thought to demand serious consideration. As to the former, it can only be said that the specific determinations in those cases have been made with as much confidence in their accuracy as may reasonably attend any work of that kind.

In connection with this statement of the grounds upon which are based the opinions advanced in the foregoing pages, it is proper to make some remarks upon the estimated value of fossils of fresh-water origin in geological determinations. As fossil mollusca are the principal forms which characterize fresh-water deposits, they alone will now be referred to. The differentiation of the mollusca into generic, family, and ordinal groups, and the diversification of specific forms among these groups, are immensely greater in marine waters than in any other. In brackish waters it is much less than in the open marine, and in lacustrine waters the minimum of differentiation is found. The large collections of fossil mollusca which have been made in different parts of the world indicate that this slight tendency to differentiation among fresh-water mollusca has always obtained in past geological time; also, that types once established have persisted through a long series of geological periods. Therefore it has become known that fossils of fresh-water origin are of little value, compared with those of marine origin, as indices of the true geological age of the strata containing them. In consequence of this, the real value of fresh-water fossils as aids in the study of stratigraphical geology has been underestimated. While it is admitted that these fresh-water forms are of little value in determining the geological age of strata, they are really of as great importance in the study of local, and even of continental, geology as are any other fossils. Indeed, it would be quite impracticable to ascertain whether the waters in which formations have been deposited were marine, brackish, or fresh, except by the character of the contained fossils.

Fresh-water formations of considerable extent can only be produced upon continental areas, and they consequently record phases of continental history of which marine formations give no indication. In Western North America the fresh-water deposits rival in extent and thickness the great marine formations; and it would have been impossible to arrive at the knowledge of them which we have now attained except by a study of their fossils. Each of these great lacustrine formations has its own distinguishing fauna, the uniform character of which over great areas is quite remarkable. So large has been the area of some of the fresh-water seas in which these deposits were formed, and so uniform the conditions under which they existed, that the geographical distribution of species in them has been nearly or quite as great as the average of that of marine mollusca. For example, some of the species of the Laramie Group have been found at points more than a thousand miles apart; and in the fresh-water Eocene groups the molluscan fauna is practically identical at points as much as 200 miles apart.

In view of the above indicated estimate of the value of fossils of fresh-water origin in the study of the geology of great continental areas, I have not hesitated to use them with confidence in the foregoing discussions.

DESCRIPTION OF SPECIES—MOLLUSCA.

UNIONIDÆ.

Genus UNIO Retzius.

UNIO MENDAX White.

(Plate IV, Figs. 2, 3, and 4.)

Unio vetustus (Meek) White, 1876; Report upon United States Geographical Surveys West of the One Hundredth Meridian, Vol. IV, p. 206, pl. xxi, fig. 12, *a*, *b*, *c*, *d*.
Unio mendax White, 1877; Bulletin of the United States Geological and Geographical Survey of the Territories, Vol. III, p. 605.
Unio mendax White, 1883; Third Annual Report United States Geological Survey, 1881–'82, p. 433, pl. 18, figs. 3, 4, 5.

Shell of medium size, subelliptical in marginal outline; valves moderately gibbous, the postero-dorsal portion of each valve more or less flattened, and in the case of the examples which are regarded as females there is a slightly increased convexity of the median portion; test somewhat thin; beaks situated near the front, inconspicuous, and only slightly elevated above the hinge line; the umbones scarcely differing in their convexity from that of the adjacent portion of the valves; anterior margin rounded by a somewhat regularly diminishing curve to the basal margin; the convexity of the latter margin sometimes slight and sometimes considerable, the difference being probably due to sex; dorsal margin nearly straight or slightly convex; posterior margin sloping downward and backward from the dorsal margin to the postero-basal extremity, which is narrowly rounded to the basal margin. Surface marked by the ordinary lines of growth. Numerous small wrinkles are usually visible upon the beaks; and two sharply-raised lines radiate from the beak upon the postero-dorsal portion of each valve. The test being somewhat light the hinge is also more delicate than is usual with shells of *Unio* of equal size, but the lateral and cardinal teeth are those of true *Unio*.

Length of an adult example, which is probably a female, 64^{mm}; height, 39^{mm}. The proportionate length of males is apparently a little more.

This species was first described by me in Volume IV, Report upon United States Geographical Surveys West of the One Hundredth Meridian (*loc. cit.*), and erroneously referred to the *U. vetustus* of Meek. The types of Meek's species came from the Bear River Laramie, while the specimens of this species came from the Wasatch strata near Wales, Utah. The specimens which I then figured and described are probably males, and their proportions differ a little from those of the specimens figured in this bulletin. These figures are copied from plate 18 of the Third Annual Report of the U. S. Geological Survey.

This is one of the plain oval types of *Unio* which has been so common in that great genus from the Jurassic period to the present time.

Indeed, it is closely like the *U. nucalis* of Meek and Hayden, which they published as coming from the Jurassic rocks in the vicinity of the Black Hills.

Locality and position.—This species has hitherto been collected only at the Desolation Cañon and Wales localities, in Utah, but it is likely to be found at any locality of the Wasatch Group in that region. Its vertical range was found to be more than 1,000 feet at the Wales locality.

UNIO RECTOIDES (sp. nov.).

(Plate IV, Fig. 1; and Plate V, Figs. 1 and 2.)

Shell transversely elongate, subelliptical in marginal outline; front margin regularly rounded; basal margin broadly convex; postero-dorsal margin sloping downward and backward to the postero-basal extremity, which is narrowly rounded to the base; beaks situated at about one-quarter of the length of the shell from the front, incurved; umbones prominent, elevated above the hinge line. Surface plain.

Length, 90^{mm}; height, 47^{mm}.

This form was found associated with *U. mendax* at the Wales locality. While the range of variation is doubtless great in all species of *Unio*, there seems to be too much difference between the form above described and *U. mendax* to allow them to be referred to the same species. The principal differences are the greater proportionate length of *U. rectoides*, the prominence of its umbones, and the greater distance of the beaks from the front. This fossil form bears some resemblance to the living *U. rectus* Lamarck.

Locality and position.—The specimen figured on Plate IV, together with some other less perfect examples, was obtained at the Wales locality. A fragment which is figured on Plate V, and which probably belongs to this species, was obtained by Professor Cope from his Puerco Group near the town of Nacimiento, New Mexico.

CYRENIDÆ.

Genus SPHÆRIUM Scopoli.

SPHÆRIUM FORMOSUM Meek and Hayden.

(Plate IV, Figs. 5 and 6.)

Cyclas formosa M. and H. Proceedings of the Academy of Natural Sciences, Phila., for 1856, p. 115.

Sphærium formosum M. and H. Proceedings of the Academy of Natural Sciences, Phila., for 1860, p. 185.

Sphærium formosum Meek, 1876. Report of the United States Geological Survey of the Territories, Vol. IX, p. 526, pl. 43, fig. 4, *a*, *b*, *c*.

Sphærium formosum White, 1883. Third Annual Report of United States Geological Survey, p. 539, pl. 17, fig. 11.

In the Wasatch strata, at the locality near Wales, Utah, some examples of a *Sphærium* were found which appear to be identical with the *S. formosum* of Meek and Hayden, the type specimens of which were obtained from the Fort Union Laramie strata. The best one of the specimens which were found at the Wales locality is represented by Figure 6 on Plate IV. Figure 5 on the same plate represents the type specimen of Meek and Hayden, it being a copy of their original figure.

LIMNÆIDÆ.

Genus LIMNÆA Lamarck.

LIMNÆA ———?

(Plate II, Fig. 13.)

A single imperfect example was found at the Wales locality, which evidently belongs to the genus Limnæa and the general aspect of which is like that of the living species, *L. columella.* No species of *Limnæa* is yet known from either the Laramie or the Wasatch Group to which this form can be properly referred; but it is possible that it is only a variety of the *L. similis* of Meek, from the Bridger Group of Southern Wyoming. The specimen is too imperfect to allow of a satisfactory specific description.

Subgenus LEPTOLIMNÆA Swainson.

LIMNÆA (LEPTOLIMNÆA) MINUSCULA White.

(Plate II, Figs. 10, 11, 12.)

Limnæa (*Leptolimnæa*) *minuscula* White, 1880; Proceedings of the United States National Museum, Vol. III, p. 160.

Limnæa (*Leptolimnæa*) *minuscula* White, 1883; Third Annual Report United States Geological Survey, p. 446, pl. 29, figs. 24 and 25.

Some imperfect examples, one of which is figured on Plate II, were found among the other fossils in the Wasatch strata at the Wales locality, which appear to belong to *L. (L.) minuscula* White. The type specimens of this species were found in strata upon the confines of the Wasatch and Green River Groups in Southern Wyoming. Figure 10 on Plate II represents one of the examples found at the Wales locality; and Figures 11 and 12 represent one of the type specimens.

Genus ACELLA Haldeman.

ACELLA MICRONEMA (sp. nov.).

(Plate II, Fig. 14.)

Among the fossils which were collected from the Wasatch strata at the Wales locality are several fragments of a small limnæid which is referable to the genus *Acella*. These fragments are sufficient to give a good idea of the outline and general character of the shell, but none of them are sufficiently perfect to be figured satisfactorily. I have therefore prepared an outline which is understood to represent the general aspect of the species, and which is given on Plate II, Fig. 14. The surface is marked by fine, distinct, uniform lines, the direction of which corresponds with the lines of growth of the shell and approximately also with its axis.

The length of adult shells was apparently from 10 to 12 millimeters. This shell is perhaps specifically identical with the form which I found associated with the preceding species in strata near the junction of the Wasatch and Green River Groups in Southern Wyoming. It is mentioned but not described on page 160, Volume III, of the Proceedings of the United States National Museum.

Genus PLANORBIS Müller.

PLANORBIS CONVOLUTUS Meek and Hayden.

(Plate II, Fig. 15.)

Planorbis convolutus M. and H., 1876; Report of the United States Geological Survey of the Territories, Vol. IX, p. 536, pl. 42, figs. 11 and 12.

Planorbis convolutus White, 1883; Third Annual Report United States Geological Survey, p. 447, pl. 27, fig. 16.

Some imperfect examples of a species of *Planorbis* were found among the other Wasatch mollusca at the Wales locality which do not seem to differ specifically from *P. convolutus* Meek and Hayden. The type specimens of *P. convolutus* came from the Laramie strata of the Upper Missouri River region; and these Wasatch specimens agree with them so closely that they cannot be regarded as anything more than a variety. A few fragments of a Planorbis were also found in the Wasatch strata near Evanston, Wyo., which probably belong to this species.

Subgenus GYRAULUS Agassiz.

PLANORBIS (GYRAULUS) MILITARIS White.

(Plate II, Figs. 16 and 17.)

Planorbis (*Gyraulus*) *militaris* White, 1880; Proceedings of the National Museum, Vol. III, p. 159.

Planorbis (*Gyraulus*) *militaris* White, 1883; Third Annual Report United States Geological Survey, p. 447, pl. 28, figs. 10 and 11.

The type specimens of this species came from near the headwaters of Soldier's Fork, Utah County, Utah, the strata containing them being a portion of the Wasatch Group. Some imperfect examples were obtained at the Wales locality. The species has also been recognized in strata upon the confines of the Green River and Wasatch Groups in

Southern Wyoming. The figures on Plate II are copies of the original figures which were published in the work last above cited.

PHYSIDÆ.

Genus PHYSA Draparnaud.

PHYSA PLEROMATIS White.

(Plate III, Figs. 1, 2, 3, 4, 5, and 6.)

Physa pleromatis White, 1875; Report upon United States Geographical Surveys West of the One Hundredth Meridian, Vol. IV, p. 211, pl. xxi, fig. 1, *a*, *b*.

Physa pleromatis White, 1883; Third Annual Report United States Geological Survey, p. 450, pl. 30, figs. 6, 7, 8.

The original specimens of this species came from Wasatch strata in Utah which are equivalent with those at the Wales locality, where numerous examples were also obtained. Specimens of this species are likewise often met with in the Wasatch strata north of the Uinta Mountains, in which region it also extends up into the base of the Green River Group.

The specimens which were collected at the Wales locality, as well as those collected elsewhere, show great variation as to form and proportions. So great is this range of variation that in the absence of intermediate forms no one would hesitate to refer the specimens showing the two extremes of variation to different species. The specimens illustrated on Plate III show much variation, but not the full extremes, especially as shown in the young.

PHYSA KANABENSIS White.

(Plate III, Figs. 11, 12, and 13.)

Physa kanabensis White, 1876; Report upon the Geology of the Uinta Mountains, by J. W. Powell, p. 119.

The original specimens of *Physa kanabensis* were obtained by Major Powell from strata in Southern Utah which he then regarded as belonging to the Laramie (Point of Rocks) Group. These were described by me (*loc. cit.*), but the specimens were too imperfect to be satisfactorily figured. Several imperfect examples of a form which probably belongs to the same species were found in the Wasatch strata at the Wales locality, already often mentioned. These specimens show that the last volution was proportionally much more inflated than the others. The original specimens of *P. kanabensis* did not show this, but it is probable that they were not fully adult. Figs. 11 and 12 represent two imperfect examples from the Wales locality and Fig. 13 is a restored outline of the full adult shell.

PHYSA BULLATA (sp. nov.).

(Plate III, Figs. 14, 15, 16, and 17?.)

Shell small, ovoid; volutions four or five in number, the last one large and ventricose; spire small and short, forming only a small part of the length of the shell. Surface marked by the usual lines of growth.

Length of one of the largest examples, 15^{mm}; greatest breadth of the same, 10^{mm}.

This species is closely like the living *P. bullata* Gould, but it seems to differ from that and from other fossil forms too much to justify its reference to any published species. A considerable number of examples of this form were collected which show a good degree of vari tion. The last volution of some of the specimens is much expanded, making the aperture very broad, but in other examples the expansion is less. The length of the spire is also variable, but it is short in all cases.

Locality and position.—Wasatch strata, near Wales, Utah; and also at several other localities in equivalent strata in the Wasatch Mountains, east of San Pete Valley.

Genus BULINUS Müller.

BULINUS ATAVUS White?

(Plate III, Figs. 7, 8, 9, and 10.)

Bulinus atavus White, 1877; Bulletin United States Geological and Geographical Survey of the Territories, Vol. III, p. 601.

Bulinus atavus White, 1880; Twelfth Annual Report of the United States Geological and Geographical Survey of the Territories, Part I, p. 86, pl. 24, fig. 5, *a*, *b*.

Bulinus atavus White, 1883; Third Annual Report of the United States Geological Survey, p. 450, pl. 25, figs. 6 and 7.

Among the fossils collected from the Wasatch strata at the Wales locality in Utah are some examples which are closely like, if not identical with, the form which I described (*loc. cit.*) under the name of *Bulinus atavus*. The Utah specimens are not quite perfect, but so far as they exhibit their specific characters they seem to differ from the type specimens only in being of smaller size. The type specimens were collected by Professor Cope from the Judith River Laramie beds in Montana.

Among the Physidæ which were collected from the Wasatch strata at the Wales locality in Utah are some more or less imperfect examples which do not seem to be referable to any of the preceding species. Some of these closely resemble the *Bulinus subelongatus* of Meek and Hayden, the types of which they obtained from the Laramie strata at the mouth of Judith River, Montana. Some fragments found in the Wasatch strata near Evanston, Southwestern Wyoming, appear also to belong to the last-named species.

ANCYLIDÆ.

Genus ACROLOXUS Beck.

ACROLOXUS ACTINOPHORUS (sp. nov.).

(Plate II, Fig. 22.)

Shell small, elongate, subelliptical in marginal outline, somewhat wider in front than behind; apex situated at a little more than one-quarter of the full length of the shell from the posterior end. Surface marked by the ordinary lines of growth, which are crossed by a multitude of minute radiating lines, the latter being visible only under a lens.

Length, 4^{mm}; breadth, 3^{mm}.

This form is possibly identical with the *A. minutus* of Meek and Hayden, from the Laramie strata at Fort Union, Mont. It seems to differ specifically from that form, however, in possessing the finely radiate markings of the surface and in being proportionally longer.

Locality and position.—Wasatch strata near the town of Wales, Utah.

HELICIDÆ.

Genus HELIX Linnæus.

HELIX NACIMIENTENSIS (sp. nov.).

(Plate V, Figs. 3, 4, 5, 6, and 7.)

Shell large, umbilicate; volutions six or seven in number, broadly convex upon the upper side, increasing regularly in width, but the depth is somewhat rapidly increased adjacent to the umbilicus upon the maturity of the shell; the periphery of the shell somewhat sharply angular in the earlier stages of growth, but it is obtusely or even obscurely so in its later stages; spire convex; apex obtuse; under surface of the last volution broadly convex from the periphery to the border of the umbilicus, which is abruptly rounded; outline of the aperture approximately semi-lunar, obtusely angular both above and below; the outer lip is apparently neither thickened nor reflexed.

Greatest diameter of the largest example in the collection, 42^{mm}; height, 33^{mm}.

This species is related to *H. peripheria* White, but it is a much larger shell, and the peripheral angle is much sharper in specimens of equal size than it is in *H. peripheria*.

Locality and position.—Puerco strata, near the town of Nacimiento, N. Mex., where it was collected by Professor Cope.

HELIX ADIPIS (sp. nov.).

(Plate V, Figs. 11 and 12.)

Shell small; spire moderately elevated; umbilicus not very broad; outer lip apparently slightly reflexed, but not materially thickened. The surface marked by regular transverse raised lines, corresponding in direction with the lines of growth.

Height, 3^{mm}; diameter, 5^{mm}.

Only two examples of this little shell were obtained, and it is possible that they are immature, but they appear to be adult. In aspect this species resembles *H. evanstonensis* White, from the Wasatch beds near Evanston, Wyo., but that shell is larger and has its umbilicus closed.

Locality and position.—Puerco Group, near the town of Nacimiento, N. Mex.; where it was obtained by Professor Cope, who found it associated with both the preceding and the following species:

PUPIDÆ.

Genus PUPA Lamarck.

PUPA LEIDYI Meek?

(Plate V, Figs. 8, 9, and 10.)

Pupa? leidyi Meek, 1873; Sixth Annual Report of the United States Geological Survey of the Territories [for 1872], p. 517.

Associated with the preceding species, and among the few shells collected by Professor Cope from his Puerco Group near the town of Nacimiento, N. Mex., are some specimens which seem to be specifically identical with *Pupa leidyi* Meek. I have never been able to find Meek's type of *P. leidyi* among the collections of the National Museum, and I am therefore obliged to rely upon his description alone. This description agrees too closely with the specimens from New Mexico to justify their reference to any other species except upon the ground that they come from different horizons. Meek's types came from the top of the Green River Group or from the base of the Bridger, while the New Mexican specimens come from a horizon which is apparently 4,000 or 5,000 feet lower.

I have shown on a previous page of this bulletin that the fresh-water series of strata is complete from the Laramie Group to the Bridger, inclusive; and there seems, therefore, to be no good reason to doubt that this molluscan form lived continuously through the whole time in which those formations were deposited.

CERIPHASIIDÆ.

Genus GONIOBASIS Lea.

GONIOBASIS TENUICARINATA Meek and Hayden.

(Plate II, Figs. 6, 7, 8, and 9.)

Melania tenuicarinata M. and H.; Proceedings of the Academy of Natural Sciences, Phila., for 1857, p. 137.

Goniobasis tenuicarinata M. and H., 1876; Report on the United States Geological Survey of the Territories, Vol. IX, p. 566, pl. 43, fig. 14, *a*, *b*, *c*.

Goniobasis tenuicarinata White, 1875; Report upon United States Geographical Surveys West of the One Hundredth Meridian, Vol. IV, p. 212, pl. xxi, fig. 10, *a*, *b*, *c*.

Goniobasis tenuicarinata White, 1883; Third Annual Report of the United States Geological Survey, p. 463, pl. 26, fig. 11.

This is one of the best known of the gasteropods of the Laramie Group, it having been found at different localities in Montana and Colorado; and it was formerly supposed to be confined to that group. The type specimens of Meek and Hayden came from the Laramie strata near Fort Union, Mont.; and the specimens which I figured in Volume IV, Explorations and Surveys (*loc. cit.*), came from the Wasatch strata at the Wales locality in Utah, as did also those represented by Figs. 6, 7, and 8, Plate II, of this bulletin. A large number of specimens have been obtained from the Wales locality which, while they vary considerably among themselves, possess all the essential characteristics of the species. Indeed, there seems to be no reason to doubt that these Wasatch specimens are in all respects specifically identical with those which have been obtained from undoubted Laramie strata.

GONIOBASIS NEBRASCENSIS Meek and Hayden.

(Plate II, Figs. 4 and 5.)

Melania nebrascensis M. and H.; Proceedings Academy Natural Sciences, Phila., for 1856, p. 124.

Goniobasis nebrascensis M. and H., 1876; Report of the United States Geological Survey of the Territories, Vol. IX, p. 565, pl. 43, fig. 12, *a*, *b*, *c*, *d*, *e*, *f*.

Goniobasis nebrascensis White, 1875; Report upon United States Geographical Surveys West of the One Hundredth Meridian, Vol. IV, p. 213, pl. xxi, fig. 9, *a*, *b*, *c*.

Goniobasis nebrascensis White, 1883; Third Annual Report United States Geological Survey, p. 463, pl. 26, figs. 15 and 16.

This species is a very variable one, and it seems to have been in part confounded with another similar form which occurs in the Laramie strata of Montana. The specimen represented by the figures on plate 26 of the work last above cited is especially referred to. Those copied figures are still more widely different from what I regard as the typical form of

G. nebrascensis by the failure of the artist to add the revolving lines which appear in Meek's original figures of the specimen. The specimens which were found at the Wales locality many years ago by Mr. G. K. Gilbert were pronounced by Mr. Meek, who then saw them, to be identical with *G. nebrascensis*. The near relationship of *G. nebrascensis* with *G. tenuicarinata*, as the two forms occur in the Wasatch strata of Utah, is quite apparent; but the difference is constant, and the two forms were not there found associated in the same layers. The form here referred to *G. nebrascensis* has also been recognized among collections which have been made from Wasatch strata near Evanston, Wyo., and in Desolation Cañon, Utah.

GONIOBASIS TENERA Hall.

(Plate II, Figs. 1 and 2.)

Cerithium tenerum Hall, 1845; Exploring Expedition Oregon and Northern California (Frémont), p. 308, pl. iii, fig. 6.
Goniobasis tenera White, 1875; Report upon United States Geographical Surveys West of the One Hundredth Meridian, Vol. IV, p. 212, pl. xxi, fig. 11, *a*, *b*, *c*.
Goniobasis tenera White, 1883; Third Annual Report of the United States Geological Survey, p. 464, pl. 31.

This species is one of the most common forms in the fresh-water Eocene strata of the West, and it ranges from the Wasatch Group to the Bridger Group inclusive. It varies so greatly in its surface markings, and also in size, that no less than five specific names have by different authors been given to forms all of which I now regard as belonging to this species. Examples of all these varieties are figured on plate 31 of the work last above cited, so arranged as to show a gradation from nearly plain to highly ornamented examples. Some imperfect examples of the typical variety *tenera* were found near the top of the series exposed at the Wales locality.

GONIOBASIS FILIFERA (sp. nov.).

(Plate II, Fig. 3.)

Some imperfect examples of a species of *Goniobasis* were found at the Wales locality, in Utah, associated with *G. tenuicarinata* and others of the forms which are described on previous pages, which evidently belong to an unpublished species. The shell is rather small, slender; the volutions convex and marked by three or more revolving raised lines, similar to those which mark the volutions of *G. tenuicarinata*. The revolving lines are only two in number in one of the examples and in another there seems to be only one. No indication of longitudinal folds, such as mark *G. tenera*, nor of fine revolving striæ, such as appear upon *G. tenuicarinata*, between the carinæ, have been observed.

RISSOIDÆ.

Genus HYDROBIA Hartmann.

HYDROBIA RECTA White.

(Plate II, Fig. 21.)

Hydrobia recta White, 1876; Geological Report of the Uinta Mountains by J. W. Powell, p. 132.

Hydrobia recta White, 1883; Third Annual Report of the United States Geological Survey, p. 466, pl. 27, fig. 38.

The original specimens of this species were obtained from the coal-bearing Wasatch strata, near Evanston, Southwestern Wyoming. Numerous imperfect examples were also found at the Wales locality, in layers associated with the coal, and also in other layers several hundred feet above the coal. These specimens were all crushed by pressure of the strata, and are otherwise imperfect, but they seem to be specifically identical with the type specimens. The latter are also imperfect. They are represented on Plate II of this bulletin.

In view of the purely fresh-water molluscan types with which these shells have been found associated there is reason to doubt whether the species ought to be referred to the genus *Hydrobia*. Perhaps it might with better reason be referred to *Bythinella* or to *Paludistrina*.

HYDROBIA UTAHENSIS White.

(Plate II, Fig. 20.)

Hydrobia utahensis White, 1876; Geological Report Uinta Mountains, J. W. Powell, p. 132.

Hydrobia utahensis White, 1883; Third Annual Report of the United States Geological Survey, p. 466, pl. 27, fig. 35.

The type specimens of this species came from the Wasatch strata at the west base of Musinia Mountain, San Pete County, Utah. It was also found in equivalent strata at the Wales locality; but the latter specimens are not well preserved. Copies of the original figures are given on Plate II of this bulletin.

In view of the close faunal relationship which the Wasatch Group is now known to hold to the Laramie, it seems not improbable that *Hydrobia utahensis* ought to be regarded as specifically identical with *H. eulimoides* Meek and Hayden. The latter was obtained from the Laramie strata of the Upper Missouri River region. The remarks which are made concerning the generic relations of the preceding species are also applicable to this.

Genus MICROPYRGUS Meek.

MICROPYRGUS MINUTULUS Meek and Hayden.

(Plate II, Fig. 24.)

Melania minutula M. and H.; Proceedings of the Academy of Natural Sciences, Phila., for 1856, p. 123.

Micropyrgus minutulus Meek, 1876; Report of the United States Geological Survey of the Territories, Vol. IX, p. 575, pl. 43, fig. 18, *a*, *b*.

Micropyrgus minutulus White, 1883; Third Annual Report of the United States Geological Survey, p. 465, pl. 26, fig. 20.

Some small shells which were found in the Wasatch strata at the Wales locality, imbedded in one of the thin limestone layers, appear to be specifically identified with *Micropyrgus minutulus* Meek and Hayden. The only apparent difference is that the Utah specimens are somewhat larger than the dimensions given by Meek and Hayden. Their type specimens came from the Fort Union Laramie strata in Montana. The figures on Plate II are copied from Meek's original figures. They are muchen larged.

VIVIPARIDÆ.

Genus VIVIPARUS Gray.

VIVIPARUS TROCHIFORMIS Meek and Hayden.

(Plate I, Figs. 1, 2, 3, 4, and 5; conf. Figs. 6 to 13.)

Viviparus trochiformis M. and H.; Proceedings of the Academy of Natural Sciences, Phila., for 1860, p. 185.

Viviparus trochiformis White, 1875; Report upon United States Geographical Surveys West of the One Hundredth Meridian, Vol. IV, p. 214, pl. xxi, fig. 4, *a*, *b*, *c*.

Viviparus trochiformis Meek, 1876; Report of the United States Geological Survey of the Territories, Vol. IX, p. 580, pl. 44, fig. 2, *a*, *b*, *c*.

Viviparus trochiformis White, 1883; Third Annual Report of the United States Geological Survey, p. 467, pl. 24, figs. 10 to 16.

Compare also with *V. leidyi*, *V. leidyi* var. *formosus*, and *V. raynoldsianus* Meek and Hayden (*loc. cit.*), and also with *V. panguitchensis* White, Third Annual Report of the United States Geological Survey, p. 467, pl. 25, figs. 19, 20, and 21.

This species was originally described by Meek and Hayden from the Laramie strata of the Upper Missouri River region. It was afterwards recognized by me among the fossils which were brought from certain strata in Utah which have since been ascertained to belong to the Wasatch group. Upon a re-examination of the collections referred to, and also a study of those which I collected during the past season at the Wales locality, I am still convinced that those Utah examples are specifically identical with the original specimens brought from Montana. Furthermore, I find in the Utah collections varietal forms which may with propriety be referred respectively to *V. leidyi* and *V. raynoldsianus*.

Again, I find among those collections intermediate forms which seem to show that these are only varieties of *V. trochiformis*. Some of these varietal forms indicate that *V. panguitchensis* ought also to be considered as a variety of *V. trochiformis*. Besides this close relationship among themselves of the forms just named, I have shown in the work last above cited the intimate relation which *Tulotoma thompsoni* White holds to *Viviparus trochiformis*.

VIVIPARUS NANUS (sp. nov.).

(Plate II, Figs. 18 and 19.)

Viviparus ——— ? White, 1875; Report upon United States Geographical Surveys West of the One Hundredth Meridian, Vol. IV, p. 215, pl. xxi, fig. 7, *a*, *b*.

Shell small, the axis short as compared with the transverse diameter; volutions five in number, regularly convex; surface plain.

Height of the largest example in the collection, 10^{mm}; greatest diameter, 8^{mm}.

When this form was first noticed by me (*loc. cit.*) the specimens then obtained would not justify the application of a new specific name. During the past season, however, I collected a considerable number of nearly perfect examples, which indicate that it really belongs to an unpublished form. I have, therefore, given it a new specific name.

Locality and position.—Wasatch strata, near Wales, Utah, and in equivalent strata at several localities in the Wasatch Mountains.

CRUSTACEA.

CYPRIDÆ.

Genus CYPRIS Müller.

CYPRIS SANPETENSIS (sp. nov.).

(Plate II, Fig. 23.)

Shell obliquely oblong in marginal outline, wider behind than before; anterior margin rounded; ventral margin straight and also a little longer than the dorsal; posterior margin gently convex, and sloping downward and a little backward from the dorsal to the ventral margin; valves moderately convex, and a very slight transverse depression is observable towards the anterior end.

Length, 2^{mm}; height, 1^{mm}.

Locality and position.—Wasatch strata near the town of Wales, Utah.

PLATE I.

PLATE I.

Page

VIVIPARUS TROCHIFORMIS AND RELATED FORMS.............................. 31

Fig. 1. Viviparus trochiformis from the Fort Union beds; a copy of Meek's type figure.

Figs. 2 and 3. Opposite views of another example, also from the Fort Union beds.

Figs. 4 and 5. Opposite views of an example from the Wasatch beds near Wales, Utah. This specimen is more elongate than usual.

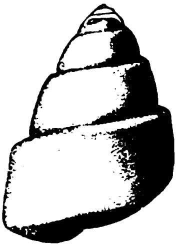
Figs. 6, 7, and 8. Views of each of the three types of *V. panguitchensis*; from Southern Utah.

Fig. 9. A copy of Meek's type figure of *V. leidyi*.

Figs. 10 and 11. Copies of Meek's figures of *V. leidyi* var. *formosus*.

Figs. 12 and 13. Copies of Meek's figures of *V. raynoldsianus*.

All figures on this plate are of natural size.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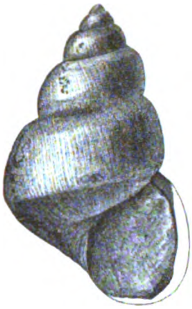
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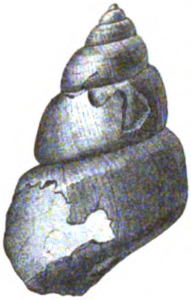
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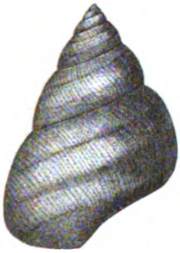
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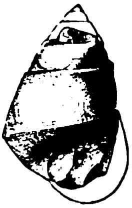
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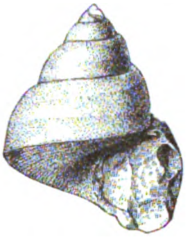
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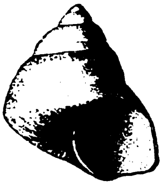
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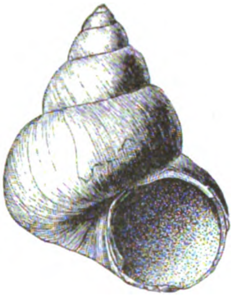
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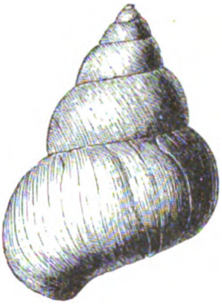
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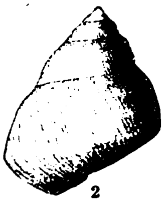
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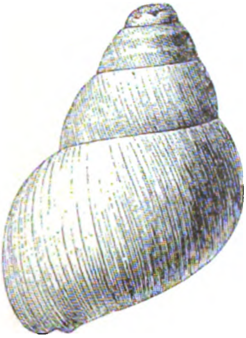
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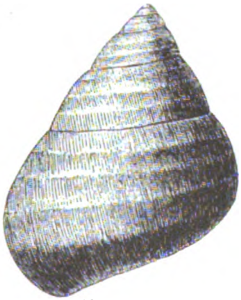
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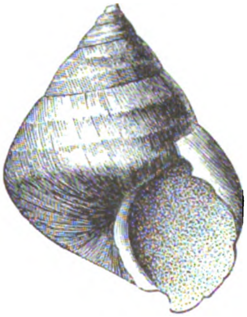
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1, 2, 3, 4, 5. **Viviparus trochiformis.**
6, 7, 8. **V. panguitchensis.**
9. **V. leidyi.**
10, 11. **V. leidyi var. formosus.**
12, 13. **V. raynoldsianus.**

PLATE II.

PLATE II.

Page.

GONIOBASIS TENERA 29

Figs. 1 and 2. Views of two typical examples; natural size.

GONIOBASIS FILIFERA 29

Fig. 3. View of one of the type specimens; enlarged.

GONIOBASIS NEBRASCENSIS 28

Figs. 4 and 5. Views of two examples from the Wasatch beds near Wales, Utah; natural size.

GONIOBASIS TENUICARINATA 28

Figs. 6, 7, and 8. Examples from the Wasatch strata near Wales, Utah; natural size.

Fig. 9. Copies of Meek's original figures of the type specimen, from the Fort Union beds.

LIMNÆA (LEPTOLIMNÆA) MINUSCULA 22

Fig. 10. An example from the Wasatch beds near Wales, Utah; enlarged.

Figs. 11 and 12. Opposite views of the type specimen, from Southern Wyoming; enlarged.

LIMNÆA ——— ? 22

Fig. 13. Lateral view of an imperfect example; natural size.

ACELLA MICRONEMA 22

Fig. 14. A restored outline; enlarged.

PLANORBIS CONVOLUTUS 23

Fig. 15. Copies of Meek's original figures.

PLANORBIS (GYRAULUS) MILITARIS 23

Figs. 16 and 17. Opposite views of one of the type specimens; enlarged.

VIVIPARUS NANUS 32

Figs. 18 and 19. Opposite views of an adult example; enlarged.

HYDROBIA UTAHENSIS 30

Fig. 20. Lateral view of the type specimen; enlarged.

HYDROBIA RECTA 30

Fig. 21. Views of the type specimens; enlarged.

ACROLOXUS ACTINOPHORUS 26

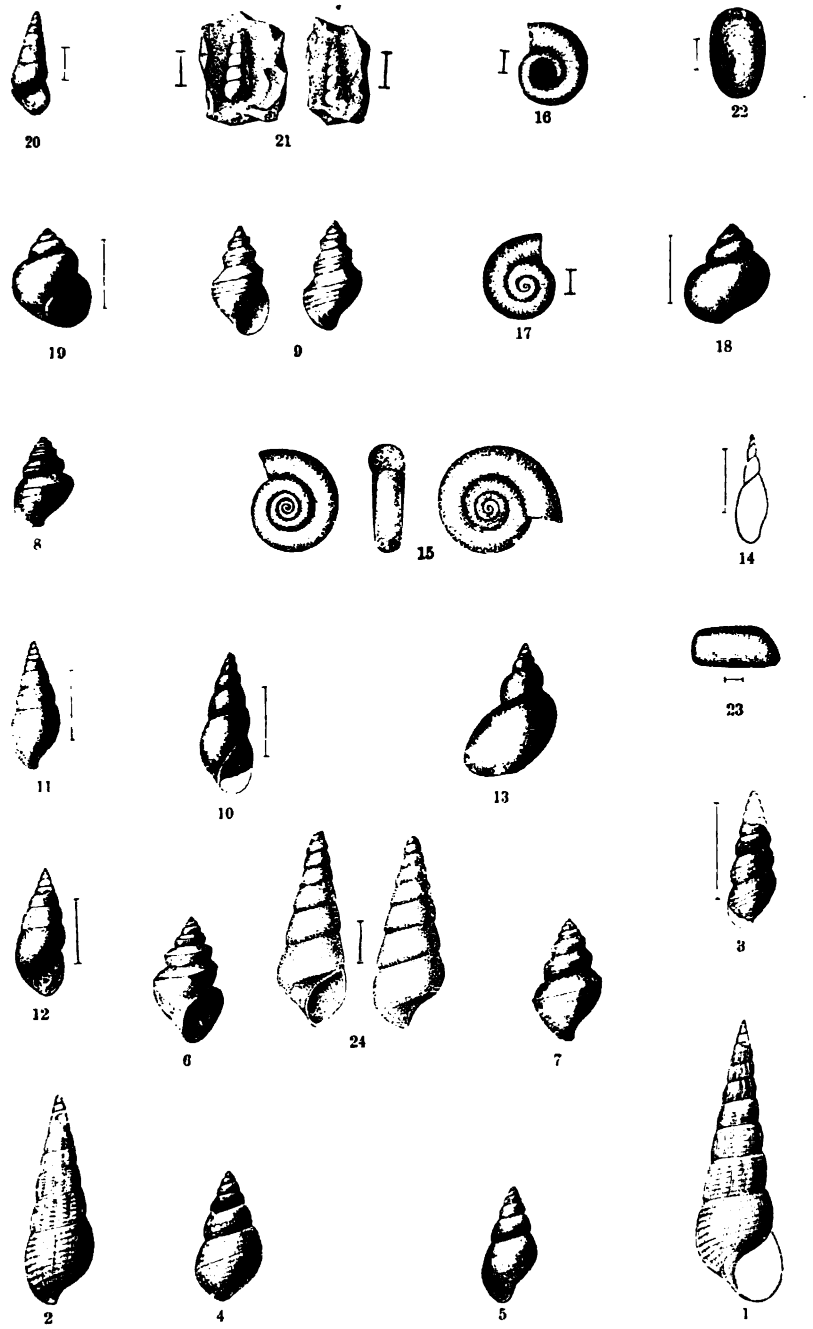
Fig. 22. Apical view of the type specimen, from the Wales locality; enlarged. The figure is a partial restoration, the specimen having been somewhat crushed.

CYPRIS SANPETENSIS 32

Fig. 23. Lateral view of a left valve; enlarged.

MICROPYRGUS MINUTULUS 31

Fig. 24. Lateral views; enlarged. After Meek.



1, 2. Goniobasis tenera.
3. G. filifera.
4, 5. G. nebrascensis
6, 7, 8, 9. G. tenuicarinata.
10, 11, 12. Limnæa (Leptolimnæa) minuscula.
13. Limnæa ——— ?
14. Acella micronema.
15. Planorbis convolutus.
16, 17. P. militaris.
18, 19. Viviparus nanus.
20. Hydrobia utahensis
21. H. recta.
22. Acroloxus actinophorus.
23. Cypris sanpetensis.
24. Micropyrgus minutulus.

PLATE III.

PLATE III.

Page.

PHYSA PLEROMATIS 24

Fig. 1. Lateral view of the type specimen; natural size.

Figs. 2 and 3. Opposite views of another example from the Wasatch beds near Wales, Utah; natural size.

Figs. 4, 5, and 6. Lateral views of other examples from the same locality.

BULINUS ATAVUS 25

Figs. 7 and 8. Copies of Meek's figures of the type specimens from the Judith River strata; natural size.

Figs. 9 and 10. Opposite views of an example from the Wasatch beds near Wales, Utah; apparently belonging to this species, although much smaller than the types.

PHYSA KANABENSIS? 24

Fig. 11. Lateral view of a crushed and imperfect example from the Wales locality; natural size.

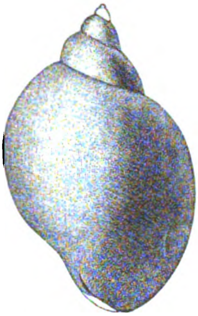
Fig. 12. Another fragment from the same locality.

Fig. 13. A restored outline of the whole shell.

PHYSA BULLATULA 25

Figs. 14, 15, and 16. Lateral views of three different examples from the Wales locality; natural size.

Fig. 17. Lateral view of an example from the same locality, perhaps belonging to this species.



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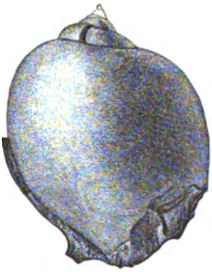

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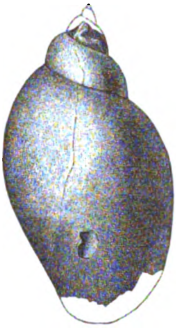

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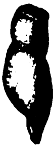

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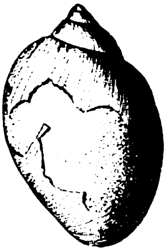

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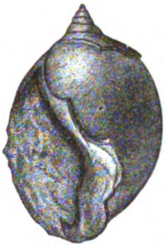

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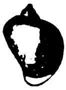

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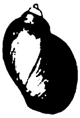

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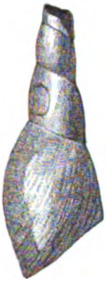

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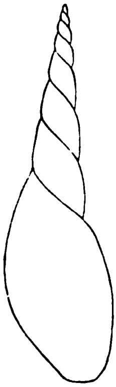

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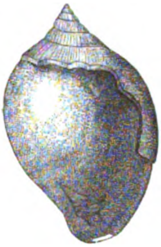

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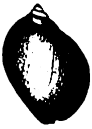

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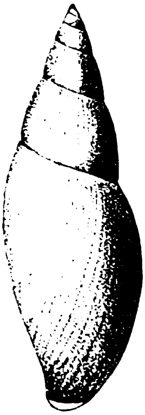

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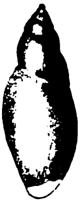

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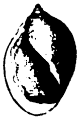

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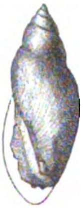

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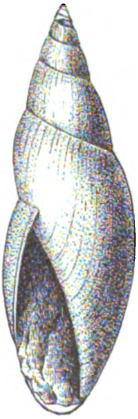

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1, 2, 3, 4, 5, 6. **Physa pleromatis.**
7, 8, 9, 10. **Bulinus atavus.**

11, 12, 13. **Physa kanabensis.**
14, 15, 16, 17. **P. bullatula.**

PLATE IV.

PLATE IV.

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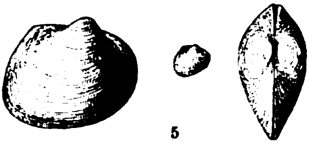
Fig. 1. Right side view; natural size.

Unio mendax 20
Fig. 2. Left side view; natural size.
Fig. 3. Right side view of a smaller example.
Fig. 4. Interior view of a portion of a right valve.

Sphærium formosum 21
Fig. 5. Copies of Meek's figures of the type specimen from the Fort Union beds; natural size and enlarged.
Fig. 6. A right valve from the Wasatch strata near Wales, Utah; enlarged.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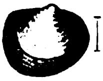
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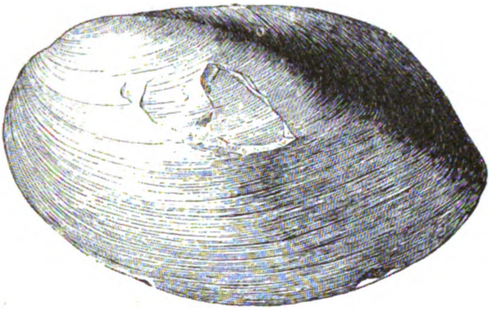
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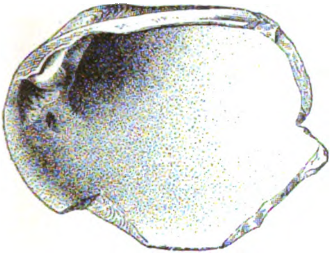
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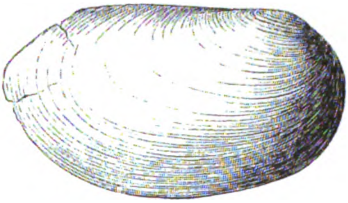
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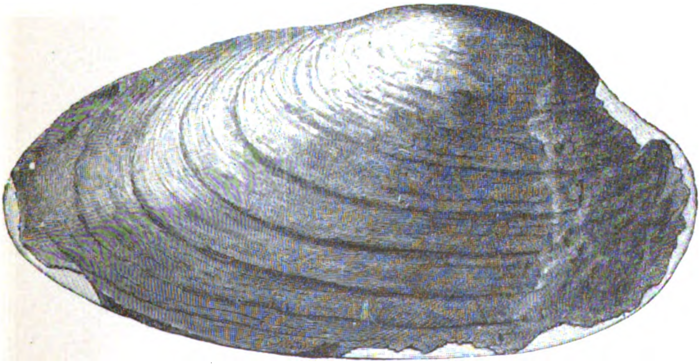
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1. Unio rectoides. **2, 3, 4. U. mendax.** **5, 6. Sphærium formosum.**

PLATE V.

PLATE V.

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UNIO RECTOIDES? 21

Figs. 1 and 2. Opposite views of a fragment of a left valve.

HELIX ADIPIS 27

Figs. 11 and 12. Lateral and apical views of one of the type specimens; enlarged.

HELIX NACIMIENTENSIS 26

Figs. 3, 4, and 5. Upper, under, and lateral views of the largest and most perfect example in the collection; natural size. The test is nearly all exfoliated.

Fig. 6. Lateral view of another example, a portion of the last volution having been distorted by pressure.

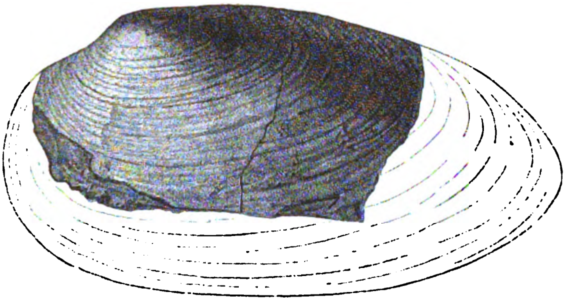
Fig. 7. An apical portion, showing the angular character of the periphery of the earlier volutions.

PUPA LEIDYI? 27

Figs. 8 and 9. Opposite views of a broken example, but the best one in the collection; enlarged.

Fig. 10. Another example, crushed and imperfect.

All the specimens figured on this plate were collected by Professor Cope from his Puerco Group, near the town of Nacimiento, N. Mex.



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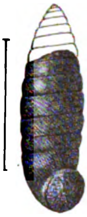

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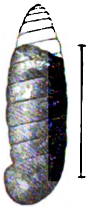

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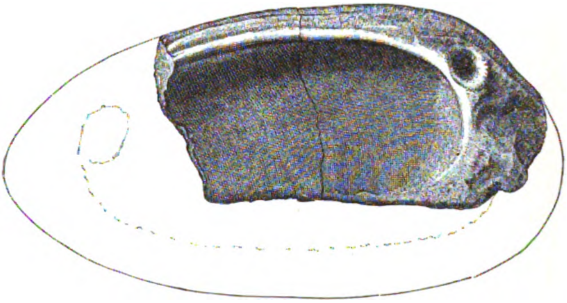

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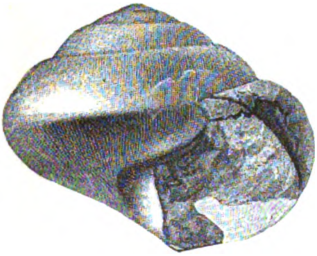

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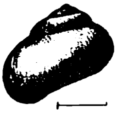

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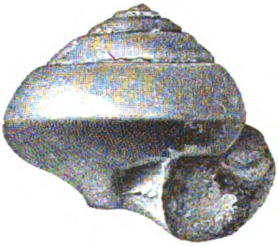

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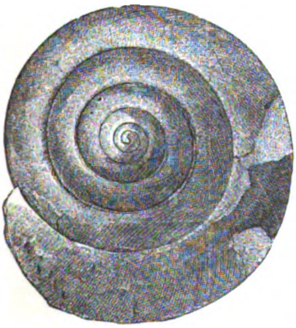

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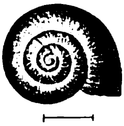

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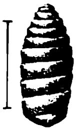

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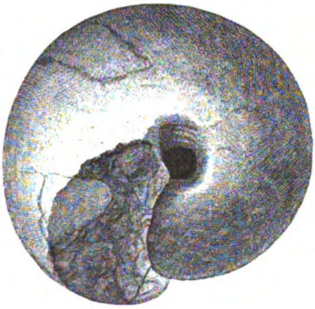

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1, 2. Unio rectoides?
3, 4, 5, 6, 7. Helix nacimientensis.

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NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume V.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 35

PHYSICAL PROPERTIES OF THE IRON-CARBURETS

WASHINGTON
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1886

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 35

WASHINGTON
GOVERNMENT PRINTING OFFICE
1886

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

80a

PHYSICAL PROPERTIES

OF

THE IRON-CARBURETS

THIRD PAPER

(PRECEDING PAPERS ON THE IRON-CARBURETS IN BULLETINS 14 AND 27)

BY

CARL BARUS AND VINCENT STROUHAL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1886

1891, Dec. 8.
Geol. Lab.

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF CHEMISTRY AND PHYSICS,
Washington, D. C., January 18, 1886.

SIR: We have the honor to transmit, through Prof. F. W. Clarke, chief chemist, the accompanying paper on the physical properties of the iron-carburets for publication as a bulletin of the Survey. The paper is offered in its present fragmentary form, owing to the circumstance that certain changes in the location of the laboratory oblige us temporarily to suspend the work. The results here presented, however, advance the inquiry to well defined stages of research, and we therefore have no hesitation about submitting them.

Our earlier work on the iron-carburets will be found in Bulletin 14 and in Bulletin 27, pp. 30 to 61.

C. BARUS.
V. STROUHAL.

Hon. J. W. POWELL,
Director United States Geological Survey.

PHYSICAL PROPERTIES OF THE IRON-CARBURETS.

By Carl Barus and Vincent Strouhal.

A. THE INTERNAL STRUCTURE OF TEMPERED STEEL.

INTRODUCTION.

Theories of magnetization usually premise homogeneity of the material carrying the magnetic quality. If the material is homogeneous, such theories still encounter formidable mathematical difficulties, and even in the favorable case of soft steel they fail to predict results which are in satisfactory accordance with experiments.[1] In proportion as the rods become hard and the internal structure becomes more and more complex, the phenomena are withdrawn from the scope of theory altogether, and must be grouped and described by a series of empiric laws. It is clear, however, that a decided step in advance of mere empiricism will have been made when the conditions of internal structure shall be fully understood. The present paper is a first endeavor in this direction. We may add that what is here said respecting magnetism will apply to other properties of steel.

In our magnetic work[2] we operated upon very thin steel rods, inferring that where diameter decreases indefinitely structure will more and more completely vanish; but to what degree this assumption is warranted for diameters within the reach of experimental methods cannot be foreseen. In other words, we do not know to what extent our results fail to express the permanent magnetization of steel, passing *homogeneously* from hard to soft. Even if it be granted that the error due to surface decarburation is nil, we have still to take into account the structural effects originally observed by Fromme.[3] We have digested his results in the accompanying table, and from these computed a few supplementary data to give the table fullness. The latter are inclosed in parentheses. In the table, M, ρ, Δ denote the mass in grammes, the radius in centimeters, and the density, respectively, of the given glass-hard rod, after the removal of the number of shells indicated in the first column. The mean radius, thickness, mass, and density of the consecutive shells are given under R, ϑ, μ, δ. The second column contains the number of days during which the rod was left in dilute acid to effect the removal of shells. Fromme determined Δ once per day. We may remark that the rod used was twice glass-hardened, and that after losing the three shells mentioned, it showed internal fissures. This led Fromme to abandon the experiment.

---

[1] Cf. U. S. Geol. Surv. Bull. 14, pp. 113, 114.

[2] Bull. 14, chaps. V, VI.

[3] C. Fromme: Wied. Ann., VIII, p. 355, 1879.

Table showing Fromme's results for structure.

Shell.	Days.	M	ρ	Δ	R	ϑ	μ	δ
0	0	30.450	(0.3537)	7.7487	....	....	....	......
1	9	29.746	(0.3504)	7.7130	(0.3520)	(0.0083)	0.704	10.5
2	16	28.043	(0.3396)	7.7412	(0.3450)	(0.0108)	1.703	7.3
3	20	27.029	(0.3340)	7.7120	(0.3368)	(0.0056)	1.014	(8.6)

It is to us a matter of no little surprise that after having obtained these startling results, the significance of which Fromme fully appreciated, he should have given the work no further consideration. The surface densities here encountered are almost incredibly large, especially so because the rod, having been twice quenched, must have been superficially decarburized, and because it was internally cracked. And yet, in spite of the dangerously small values of ϑ, the values for Δ are so pronounced that the data for δ must in their general variations be correct. Hence these abnormal values, and the probable occurrence of changes of strain implied, together with intimations of singular periodic relations, give this short series of results unusual physical importance.

Guided by these data, many of our experiments were made chiefly with reference to surface effects. Nevertheless, our main object in this paper is to follow the phenomenon of structure throughout comparatively great ranges of depth. Hence our shells are necessarily[1] chosen thicker (0.01^{cm} to 0.1^{cm}), and for this reason, possibly, we did not detect the enormous condensation of Fromme's filmy shells, if, indeed, in the steel examined such densities existed. Aside from this difference in degree, in the method chosen, and in the material employed our results corroborate the data of Fromme in a general way. We also encounter harmonic variations of δ which appear to be actual occurrences, inasmuch as they cannot satisfactorily be referred to periodic distributions of errors.

APPARATUS.

Steel.—Our steel, as we subsequently found, was not the best for the purpose, being a coarse-grained metal, quite brittle in the glass-hard state. This steel readily cracks on quenching, easily loses carbon at the surface, and is probably incapable of carrying more than small values of stress. If the temperature before quenching be too high, the superficial layers rarely show hardness at all. All this taken together may explain why the values of density in hand vary within an interval so much smaller than was the case in Fromme's investigation. Some of our experiments, however, were made with other kinds of steel. *A priori* there is no reason why results for the structure of the material in question are not just as important as results for the structure of any other kind of steel. The objectionable qualities enumerated have indeed led to some special results. We show in the sequel that the chemical constitution of steel is one of the essential factors determining structure; that in a full investigation it will be necessary to extend the experiments to as many kinds of steel as possible.

---

[1] It is impossible to retain perfect cylindricity when many shells are removed by solution. See p. 49.

In all cases, however, the mechanical hardness exhibited by our steel in the tempered state was exceptionally great. Moreover, the density interval hard-soft is here as large as we have found it in any other kind of steel. It appears, indeed, that the magnitude of this interval is modified chiefly by carburation, and that for moderate thicknesses it is almost independent of dimensions—a deduction at variance with earlier results of Fromme and our own. Cylindrical figures were operated on in all cases.

Crucible.—To impart to the thick steel cylinders the desirable uniformity of red heat before quenching, they were heated in a cylindrical iron box (height 8.5^{cm}, diameter 4^{cm}, inside measure) made of gas-pipe supplies. The box was heavily coated with oxide internally, and the cylinder was placed therein on a layer of asbestus, as shown in Fig. 1.

This apparatus is introduced into a large Fletcher crucible furnace and heated to the degree of redness necessary. The temperature of the cylinder must be specially observed from time to time by momentary removals of the lid. The iron box is further useful, inasmuch as oxidation, carburation, and decarburation are very nearly avoided. The surfaces of the cylinders remain smooth, showing the colored films only.

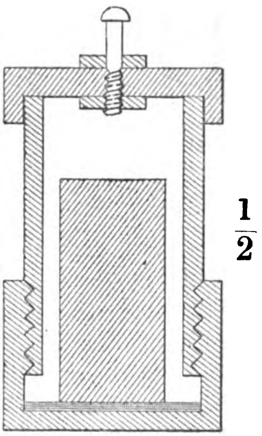

FIG. 1. Crucible for heating steel.

Apparatus for quenching.—This apparatus is also made of gas-pipe supplies, as shown in Fig. 2. When in use it is placed vertically in the neighborhood of a hydrant, and a swift current of water is passed through it, as indicated by the arrows. Dimensions of main reservoir: Length, 25^{cm}; diameter, 5^{cm}, inside measure. Diameter of supply-tube, 2.5^{cm}. Near the lower end of the apparatus is a false bottom of wire gauze, *a a*, held in place by an iron ring. The object of this is to hold the steel suspended in the current. The cylinder, having been heated to the temperature desired, is carried to the quencher in the (closed) crucible; after this the lid is quickly taken off, and the cylinder is dropped into the water. The advantages and disadvantages of quenching in a current of water have so frequently been discussed that comment is unnecessary here. It is certainly the best method for the present purposes.

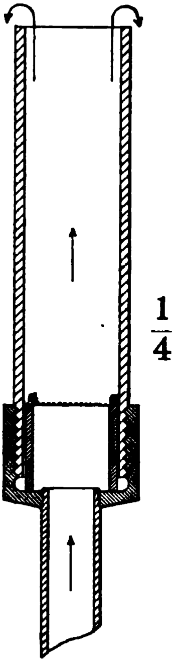

FIG. 2. Apparatus for quenching steel.

Cell for solution.—For the purpose of removing consecutive shells from the cylinder, we tried at first to use a carbon-pointed master-tool on the lathe. But steel is too tenacious and diamond too brittle; so that even in the case of stones ground with sharp cutting edges the work is rather scraped or ground than cut. The progress made is therefore exceedingly slow, and the utmost care must be taken to avoid appreciable rise of temperature from friction. This tedious process was therefore rejected, and a method in which the shells are removed by galvanic solution was used in its stead. After solution the cylinders were trued and smoothed as far as necessary by the diamond point, scraping under a current of water.

In order to secure uniformity of solution over the whole cylindrical surface of the steel, we devised the special cell figured in the diagram, Fig. 3 (page 15). This consists essentially of a steel clamp, *c a b d e c*, the ends of which are sharpened conically, and fit into conical depressions, *c c*, in the end surfaces of the cylinder operated upon. A drum, *A B D E*, the cylindrical surface of which is of sheet copper, with the ends *A B* and *D E* closed by plates of suitably perforated vulcanite, surrounds the cylinder symmetrically on all sides. The steel arm *a c* passes through the center of the upper plate. The lower plate has a much larger perforation, enabling the drum to slide easily over the cylinder and fitted to a wooden collar, *F F*.

Together with the side of clamp *e d*, the collar *F F* serves as a kind of foot for the apparatus. When in use the cell is plunged into a large vessel containing the electrolyte, and is submerged at least above the upper face *A B* of the drum. To prevent corrosion, the clamp *c a b d e c* is completely enveloped in an insulating coat of rubber hose. For the same purpose the ends of the cylinder are painted with asphaltum. Having sprung it into position, the insulation of the clamp is made continuous with the insulation on the ends of the cylinder by covering all exposed parts with a thick layer of paraffine.

The current enters the clamp at $+a$, passing into the cylinder from both ends; thence across the electrolyte to the drum; finally by the gutta-percha-covered wire $B-$ back to the battery. It is well to cover the *inner* surface of the drum, above the upper and below the lower planes of the ends of the cylinder, with asphaltum. In this case the axes of the tubes of flow are radial lines. In other cases they are crowded either near the ends or near the equatorial parts of the cylinder, and solution takes place at greater rates in those parts.

Two to ten Grove cells, flat pattern, vulcanite cups, connected either in series or in multiple arc, supplied the amount of current necessary. These cells are by no means constant, and are practically exhausted for the present purposes in two hours. The quantity of steel dissolved without current being slight, we were able to supervise and regulate the rate of solution satisfactorily by inserting a Siemens' amperimeter. The whole process was therefore well under control. Usually the strength of current was so chosen as to dissolve an average total amount of 10 g. to 15 g. during each experiment.

The following little table, selected at random from many data, contains the statistics of solution and exhibits the mean efficiency of the battery (current in ampères) perspicuously:

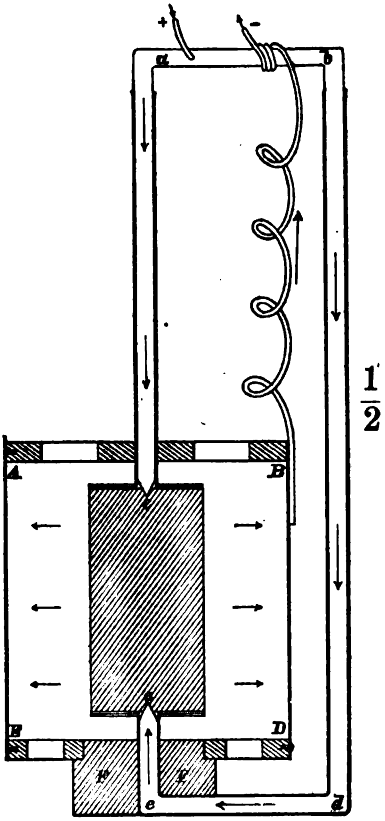

FIG. 8. Holder for galvanic solution.

Time.		Current.	Time.		Current.
h.	m.		h.	m.	
10	10	3.0	10	55	10.5
	15	8.7		60	9.3
	20	11.0	11	5	8.4
	25	12.2		10	7.4
	30	12.8		15	6.9
	35	13.0		25	5.8
	40	12.8		45	3.6
	45	12.2	12	15	0.5
	50	11.3			

During the solution of superficial shells the cylinders frequently showed symmetrical furrows and ridges, probably indicative of certain varieties of structure of the soft bars. Usually, however, the surfaces were merely rough and pitted, heavily coated with carbon, somewhat irregular; so that truing with the diamond is indispensable. In some rare instances glossy surfaces appeared, or again rough surfaces partially mottled with glossy patches. All this is probably connected with the passivity of iron. Solution is best effected in dilute hydrochloric acid. In the case of dilute sulphuric acid the occurrence of passive iron and reduced rates of solution are a frequent annoyance. The ferric chlorides attack copper, and are therefore objectionable. Solution in oxalates, though distinctly perceptible, is practically nil.[1]

The central depressions or holes in the end surfaces of the steel cylinders have thus far been described only as subserving the purposes of holding the cylinders in the dissolving cells, and (during truing) in the lathe. But they are further useful, in the density work in question, as a means for attaching the suspension. This is clearly shown in the annexed cut, Fig. 4. This method of fastening is again employed in the resistance measurements.

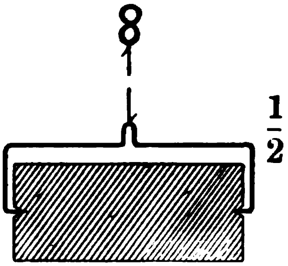

Fig. 4.—Method of suspension.

EXPERIMENTAL RESULTS.

Results for density.—The results of our measurements are given in the following tables, and it has been our endeavor so to arrange them that data referring to cores and shells of like order may be easily compared.

Table 1 contains the constants of the cylinders in the soft state, in which they reached our hands. M is the weight in grammes for the length l and diameter 2ρ of cylinder. The latter dimension was determinable with some accuracy by means of a small spherometer. Using this datum and the known density we calculated l. In case of cylinders as thick as these, it is not easy to obtain accurate mean values for l by mere measurement. But the difference between observed and calculated l in the tables is almost wholly due to the differences in the factors of the two centimeter scales (spherometer screw and rule) employed. Δ_t is the observed density at t°. From this we computed Δ, the density at 0°, and v, the corresponding value for specific volume (volume of the unit of mass), by accepting 0.000036 as the coefficient of cubical expansion of steel.

TABLE 1.—*Data for the commercial (soft) state.*

No.	M	l observed.	l calculated.	2ρ observed.	t	Δ_t	Δ	Mean Δ	v
	g.	*cm.*	*cm.*	*cm.*	°*C.*				
1.....	832.4745	5.96	6.013	3.0006	24.6	7.8268	7.8337	7.8337	0.127654
2.....	832.4955	5.98	6.024	2.9953	24.0	7.8270	7.8337	7.8337	0.127654
3.....	149.8985	5.97	6.006	2.0139	24.0	7.8296	7.8363	7.8363	0.127612
4.....	149.9675	5.97	6.024	2.0118	23.8	7.8304	7.8371	7.8371	0.127598
5.....	37.6219	6.00	6.026	1.0085	24.0	7.8270	7.8338	7.8350	0.127633
5.....	37.6217	....	....	....	26.8	7.8287	7.8362		

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[1] We are indebted to Prof. F. A. Gooch for advice in much of this work.

Tables 2 and 3 contain the first series of results. As above, M, ρ, t, Δ, ∇ are the symbols of mass, radius, temperature, density, specific volume, respectively, of the cores. Again, R, ϑ, μ, δ are, respectively, the symbols of mean radius, thickness, mass, density of the elementary shells. If we denote the number of the shell by a subscript, and if the first core be the volume of cylinder left *after* removing the first shell, then the relations between the quantities in the tables are succinctly these:

$$\nabla_n = 1 \mid \Delta_n \qquad R_n = \frac{1}{2}(\rho_{n-1} + \rho_n)$$

$$\vartheta = \rho_{n-1} - \rho_n \qquad \mu_n = M_{n-1} - M_n$$

$$\delta_n = \Delta_{n-1} + \frac{\rho_n}{2\vartheta_n}(\Delta_{n-1} - \Delta_n) \quad . \ . \ . \quad \text{(observed)}$$

$$\delta_n = \frac{\mu_n}{M_{n-1}\nabla_{n-1} - M_n\nabla_n} \quad . \ . \ . \ . \ . \quad \text{(calculated)}$$

This distinction between observed and calculated is not quite rigid, because both data involve Δ, but the other quantities are different.

Tables 4 and 5 contain the second series of results, and are constructed on the same plan as Tables 2 and 3. Little further explanation is therefore required. When observations of Δ were made on different days, the date of each is usually given. We may remark that in these and the preceding tables "diameter observed" is usually the mean of ten measurements made with a screw micrometer caliper. In the case of rough surfaces, where frequent repetitions are essential, this instrument is preferable to the spherometer. Except where otherwise stated, the surface has been turned smooth by the diamond.

To facilitate comparison Tables 2 and 3 are printed in parallel form (pp. 18–23), as are also Tables 4 and 5 (pp. 24–27).

TABLE 2.—*Cylinders in the glass-hard state. Constants of the consecutive cores. First series of measurements.*

[$l = 6$ cm. approximately.]

$M_0, \rho_0, \varDelta_0, \nabla_0$.

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	∇	Remarks.
1	332.1020	1.5041	1.5054	21.3	7.7680	7.7738	7.7744	0.128627	
	....	....	....	24.2	7.7684	7.7750	....	....	
3	149.7442	1.0112	1.0123	22.7	7.7457	7.7521	7.7520	0.128996	
	....	....	....	24.0	7.7454	7.7520	....	....	
5	87.5913	0.5081	....	22.4	7.7381	7.7442	7.7442	0.129129	
	....	....	....	18.2	7.7393	7.7443	....	....	

$M_1, \rho_1, \varDelta_1, \nabla_1$.

1	321.9877	1.4832	1.4823	23.1	7.7671	7.7735	7.7734	0.128644	
	....	....	....	26.3	7.7663	7.7734	....	....	
3	146.4123	0.9996	1.0012	23.9	7.7419	7.7485	7.7485	0.129057	
	....	....	....	25.2	7.7417	7.7486	....	....	

$M_2, \rho_2, \varDelta_2, \nabla_2$.

1	307.0620	1.4500	1.4477	21.9	7.7667	7.7728	7.7727	0.128655	
	....	....	....	21.9	7.7665	7.7726	....	....	
3	132.5652	0.9582	0.9528	21.8	7.7411	7.7472	7.7469	0.129084	
	....	....	....	21.8	7.7403	7.7464	....	....	

$M_3, \rho_3, \varDelta_3, \nabla_3$.

1	292.8284	1.4164	1.4124	21.6	7.7685	7.7746	7.7742	0.128631	
	....	....	....	22.9	7.7673	7.7737	....	....	
3	119.1982	0.9051	0.9036	22.0	7.7384	7.7445	7.7453	0.129111	
	....	....	....	22.6	7.7396	7.7460	....	....	

$M_4, \rho_4, \varDelta_4, \nabla_4$.

1	280.3889	1.3895	1.3888	21.1	7.7677	7.7735	7.7734	0.128644	
	....	....	....	22.2	7.7671	7.7732	....	....	
3	107.1745	0.8636	0.8566	21.4	7.7417	7.7476	7.7479	0.129067	
	....	....	....	22.0	7.7421	7.7482	....	....	

$M_5, \rho_5, \varDelta_5, \nabla_5$.

1	269.8968	....	1.3571	22.0	7.7687	7.7748	7.7750	0.128617	
	....	....	....	22.1	7.7690	7.7751	....	....	
3	91.0238	....	0.7894	21.8	7.7421	7.7482	7.7486	0.129056	
	....	....	....	22.0	7.7430	7.7491	....	....	

TABLE 3.—*Cylinders in the glass-hard state. Constants of the consecutive elementary shells. First series of measurements.*

[$l = 6$ cm. approximately.]

No.	R observed.	R calculated.	ϑ observed.	ϑ calculated.	μ	δ observed.	δ calculated.	Remarks.
	$R_0, \vartheta_0, \mu_0, \delta_0.$							
1	....	....	....	....	....	....	....	
3	....	....	....	....	....	....	....	Longitudinal crack apparent in the mantle of the cylinder.
5	....	....	....	....	....	....	....	Longitudinally cracked.
	First shell. $R_1, \vartheta_1, \mu_1, \delta_1.$							
1	1.4936	1.4939	0.0209	0.0231	10.1643	7.809	7.806	Shell filable; removed with hard-steel master tools.
3	1.0004	1.0068	0.0116	0.0111	3.3319	7.904	7.914	Do.
	Second shell. $R_2, \vartheta_2, \mu_2, \delta_2.$							
1	1.4666	1.4650	0.0332	0.0346	14.8757	7.775	7.792	Shell not filable; dissolved off galvanically. Trued with diamond; shell very hard.
3	0.9764	0.9770	0.0465	0.0484	13.8471	7.765	7.762	Same. Longitudinal and transverse cracks appear distinctly.
	Third shell. $R_3, \vartheta_3, \mu_3, \delta_3.$							
1	1.4332	1.4301	0.0336	0.0353	14.7836	7.741	7.738	
3	0.9291	0.9282	0.0481	0.0492	13.3670	7.762	7.763	Vertical and transverse cracks or crevices visible.
	Fourth shell. $R_4, \vartheta_4, \mu_4, \delta_4.$							
1	1.4030	1.3978	0.0269	0.0291	11.9395	7.795	7.794	Surface shows scaly fracture.
3	0.8858	0.8801	0.0415	0.0470	12.0237	7.718	7.723	Do.
	Fifth shell. $R_5, \vartheta_5, \mu_5, \delta_5.$							
1	....	1.3702	0.027	0.0262	10.4921	....	7.738	
3	....	0.8230	0.068	0.0672	16.1507	....	7.744	

TABLE 2.—*Cylinders in the glass-hard state. Constants of the consecutive cores. First series of measurements*—Continued.

$M_6, \rho_6, \Delta_6, \nabla_6$.

No.	M	ρ observed.	ρ calculated.	t	Δt	Δ	Mean Δ	∇	Remarks.
1	246.7909	1.3026	1.2974	19.5	7.7732	7.7785	7.7784	0.128561	
				20.8	7.7724	7.7782			
3	71.6405	0.7068	0.7002	19.0	7.7472	7.7425	7.7532	0.128979	
				21.4	7.7481	7.7439			

$M_7, \rho_7, \Delta_7, \nabla_7$.

No.	M	ρ observed.	ρ calculated.	t	Δt	Δ	Mean Δ	∇	Remarks.
1	225.8279	1.2556	1.2408	19.5	7.7756	7.7812	7.7813	0.128518	
				20.8	7.7756	7.7814			
3	56.7829	0.6312	0.6232	20.0	7.7507	7.7563	7.7566	0.128923	
				21.2	7.7517	7.7568			

$M_8, \rho_8, \Delta_8, \nabla_8$.

No.	M	ρ observed.	ρ calculated.	t	Δt	Δ	Mean Δ	∇	Remarks.
1	211.2518	1.2038	1.2001	18.8	7.7767	7.7820	7.7817	0.128507	
				19.8	7.7758	7.7814			
3	43.2270	0.5989	0.5438	19.2	7.7478	7.7581	7.7588	0.128969	
				22.0	7.7475	7.7536			

$M_9, \rho_9, \Delta_9, \nabla_9$.

No.	M	ρ observed.	ρ calculated.	t	Δt	Δ	Mean Δ	∇	Remarks.
1	199.6350	1.1759	1.1664	21.6	7.7780	7.7841	7.7841	0.128467	
				22.0	7.7780	7.7841			
3	36.1996	0.5036	0.4975	22.0	7.7532	7.7593	7.7595	0.128874	
				22.5	7.7536	7.7598			

$M_{10}, \rho_{10}, \Delta_{10}, \nabla_{10}$.

No.	M	ρ observed.	ρ calculated.	t	Δt	Δ	Mean Δ	∇	Remarks.
1	183.2372	1.1258	1.1175	21.8	7.7805	7.7866	7.7869	0.128421	
				21.9	7.7811	7.7872			
3	29.7464	0.4608	0.4508	21.9	7.7561	7.7622	7.7637	0.128804	
				21.5	7.7591	7.7652			

$M_{11}, \rho_{11}, \Delta_{11}, \nabla_{11}$.

No.	M	ρ observed.	ρ calculated.	t	Δt	Δ	Mean Δ	∇	Remarks.
1	166.7330	1.0725	1.0656	21.4	7.7834	7.7893	7.7894	0.128380	
				21.2	7.7837	7.7895			
3	25.0084	0.4182	0.4134	21.5	7.7558	7.7618	7.7621	0.128831	
				21.0	7.7566	7.7624			

$M_{12}, \rho_{12}, \Delta_{12}, \nabla_{12}$.

No.	M	ρ observed.	ρ calculated.	t	Δt	Δ	Mean Δ	∇	Remarks.
1	149.7915	1.0269	1.0099	19.2	7.7866	7.7919	7.7919	0.128333	
3	20.4688	0.3771	0.3734	17.4	7.7598	7.7646	[illegible]	0.128773	
	20.3482			19.0	7.7613	7.7666			

TABLE 3.—*Cylinders in the glass-hard state. Constants of the consecutive elementary shells. First series of measurements*—Continued.

Sixth shell. $R_6, \vartheta_6, \mu_6, \delta_6$.

No.	R observed.	R calculated.	ϑ observed.	ϑ calculated.	μ	δ observed.	δ calculated.	Remarks.
1	1.3298	1.3272	0.0545	0.0597	23.1059	7.734	7.741	
3	0.7481	0.7448	0.0826	0.0892	19.3838	7.729	7.733	

Seventh shell. $R_7, \vartheta_7, \mu_7, \delta_7$.

1	1.2791	1.2691	0.0470	0.0566	20.9630	7.740	7.747	
3	0.6690	0.6617	0.0756	0.0770	14.8576	7.739	7.740	Curiously glossy after solution; crack still perceptible.

Eighth shell. $R_8, \vartheta_8, \mu_8, \delta_8$.

1	1.2295	1.2204	0.0522	0.0407	14.5761	7.777	7.775	
3	0.5901	0.5835	0.0828	0.0794	12.5559	7.767	7.765	

Ninth shell. $R_9, \vartheta_9, \mu_9, \delta_9$.

1	1.1896	1.1832	0.0275	0.0387	11.6168	7.730	7.741	
3	0.5262	0.5206	0.0458	0.0463	7.0274	7.722	7.726	

Tenth shell. $R_{10}, \vartheta_{10}, \mu_{10}, \delta_{10}$.

1	1.1507	1.1420	0.0506	0.0489	16.3978	7.753	7.751	
3	0.4818	0.4742	0.0433	0.0467	6.4532	7.737	7.740	

Eleventh shell. $R_{11}, \vartheta_{11}, \mu_{11}, \delta_{11}$.

1	1.0969	1.0915	0.0528	0.0519	16.5042	7.758	7.762	
3	0.4386	0.4321	0.0421	0.0374	4.7380	7.772	7.772	

Twelfth shell. $R_{12}, \vartheta_{12}, \mu_{12}, \delta_{12}$.

1	*1.0497	†1.0377	*0.0456	†0.0557	16.9415	7.761	7.768	* Rough. † Smooth.
3	*0.3976	†0.3984	*0.0410	†0.0400	4.5999	7.746	7.747	

TABLE 2.—*Cylinders in the glass-hard state. Constants of the consecutive cores. First series of measurements*—Continued.

$M_{13}, \rho_{13}, \Delta_{13}, \nabla_{13}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	138.8822	0.9792	0.9714	18.7	7.7837	7.7890	7.7911	0.128352	
	138.2607			21.9	7.7872	7.7933			
2		0.3354							

$M_{14}, \rho_{14}, \Delta_{14}, \nabla_{14}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	127.5671	0.9417	0.9319	21.6	7.7878	7.7989	7.7987	0.128308	
	127.5652			23.1	7.7872	7.7986			
2		0.2850							

$M_{15}, \rho_{15}, \Delta_{15}, \nabla_{15}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	117.4398	0.9023	0.8939	22.2	7.7914	7.7975	7.7979	0.128239	
	117.4414			20.0	7.7927	7.7983			

$M_{16}, \rho_{16}, \Delta_{16}, \nabla_{16}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	106.8649	0.8651	0.8526	19.8	7.7954	7.8010	7.7999	0.128207	
	106.8635			21.1	7.7942	7.7988			

$M_{17}, \rho_{17}, \Delta_{17}, \nabla_{17}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	97.9882	0.8251	0.8161	19.8	7.7961	7.8017	7.8017	0.128177	
	97.9874			21.2	7.7952	7.8010			

$M_{18}, \rho_{18}, \Delta_{18}, \nabla_{18}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	86.1986	0.7767	0.7656	20.5	7.7961	7.8017	7.8018	0.128184	Equatorial parts just filable.
	86.1981			22.2	7.7947	7.8008			

$M_{19}, \rho_{19}, \Delta_{19}, \nabla_{19}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	74.8681	0.7238	0.7135	21.5	7.7973	7.8031	7.8027	0.128161	Fileable.
	74.8673			23.0	7.7960	7.8024			

$M_{20}, \rho_{20}, \Delta_{20}, \nabla_{20}.$

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
1	61.4094	0.6515	0.6462	19.4	7.7973	7.8026	7.8009	0.128190	Fileable.
	61.4078			22.2	7.7931	7.7992			

TABLE 3.—*Cylinders in the glass-hard state. Constants of the consecutive elementary shells. First series of measurements*—Continued.

Thirteenth shell. R_{13}, ϑ_{13}, μ_{13}, δ_{13}.

No.	*R* observed.	*R* calculated.	ϑ observed.	ϑ calculated.	μ	δ observed.	δ calculated.	Remarks.
1	*1.0031	†0.9907	*0.0477	†0.0385	11.2200	7.800	7.800	*Rough. †Smooth.
3	0.3563	....	0.0417	....	....	....	....	

Fourteenth shell. R_{14}, ϑ_{14}, μ_{14}, δ_{14}.

1	0.9605	0.9516	0.0375	0.0395	11.0064	7.762	7.758	
3	0.3102	....	....	....	....	....	....	No. 3 broken.

Fifteenth shell. R_{15}, ϑ_{15}, μ_{15} δ_{15}.

1	0.9220	0.9129	0.0394	0.0380	10.1258	7.746	7.745	

Sixteenth shell. R_{16}, ϑ_{16}, μ_{16}, δ_{16}.

1	0.8837	0.8733	0.0372	0.0413	10.5761	7.775	7.778	

Seventeenth shell. R_{17}, ϑ_{17}, μ_{17}, δ_{17}.

1	0.8451	0.8343	0.0399	0.0365	8.9264	7.781	7.780	

Eighteenth shell. R_{18}, ϑ_{18}, μ_{18}, δ_{18}.

1	0.8009	0.7908	0.0485	0.0505	11.7445	7.805	7.805	Equatorial parts filable.

Nineteenth shell. R_{19}, ϑ_{19}, μ_{19}, δ_{19}.

1	0.7502	0.7395	0.0529	0.0521	11.3256	7.792	7.793	

Twentieth shell. R_{20}, ϑ_{20}, μ_{20}, δ_{20}.

1	0.6876	0.6799	0.0723	0.0673	13.4591	7.811	7.810	

TABLE 4.—*Cylinders in the glass-hard state. Constants of the consecutive cores. Second series of measurements.*

[l=6 cm. approximately.]

$M_0, \rho_0, \Delta_0, \nabla_0$.

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	∇	Remarks.
2	332.2677	1.5010	1.5043	22.2	7.7841	7.7902	7.7900	0.128370	
	....	....	....	22.2	7.7837	7.7398	....	....	
4	149.8939	1.0133	1.0114	22.0	7.7678	7.7739	7.7740	0.128634	
	....	....	....	17.8	7.7690	7.7740	....	....	
6	115.3561	0.8919	0.8855	22.2	7.7975	7.8036	7.8039	0.128141	
	....	....	....	17.9	7.7992	7.8042	....	....	

$M_1, \rho_1, \Delta_1, \nabla_1$.

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	∇	Remarks.
2	321.1428	1.4785	1.4785	23.9	7.7798	7.7864	7.7878	0.128406	Rough. Oct. 29, 1885.
	320.6418	....	....	19.4	7.7839	7.7892	....	....	Smooth. Oct. 31, 1885.
[a]4	144.7017	0.9970	0.9938	23.8	7.7661	7.7727	7.7733	0.128645	Oct. 29, 1885.
	144.7017	....	....	19.8	7.7682	7.7738	....	....	Oct. 31, 1885.
[a]6	108.1191	0.8653	0.8575	23.6	7.7934	7.8000	7.8011	0.128187	Oct. 29, 1886.
	108.1191	....	....	19.8	7.7966	7.8022	....	....	Oct. 31, 1585.

[a] Difference in Δ possibly the result of shrinkage.

$M_2, \rho_2, \Delta_2, \nabla_2$.

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	∇	Remarks.
2	310.9500	1.4558	1.4549	20.3	7.7832	7.7888	7.7894	0.128380	Rough.
	310.6535	....	....	21.2	7.7842	7.7900	....	....	Smooth.
4	136.9445	0.9688	0.9663	19.4	7.7681	7.7734	7.7743	0.128629	Rough.
	136.7036	....	....	19.6	7.7697	7.7753	....	....	Smooth.
6	100.5121	0.8314	0.8260	20.0	7.7924	7.7980	7.7997	0.128210	Rough.
	100.1245	....	....	20.1	7.7959	7.8015	....	....	Smooth.

$M_3, \rho_3, \Delta_3, \nabla_3$.

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	∇	Remarks.
2	297.6610	1.4260	1.4237	22.2	7.7849	7.7910	7.7912	0.128350	
	297.6550	....	....	22.3	7.7853	7.7914	....	....	
4	126.3200	0.9327	0.9284	22.0	7 7690	7.7751	7.7750	0.128617	
	126.3191	....	....	23.4	7.7685	7.7749	....	....	
6	89.6386	0.7876	0.7809	21.2	7.7929	7.7987	7.7985	0.128230	
	89.6377	....	....	23.7	7.7920	7.7984	....	....	

$M_4, \rho_4, \Delta_4, \nabla_4$.

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	∇	Remarks.
2	285.8320	1.4001	1.3950	22.0	7.7865	7.7926	7.7923	0.128332	
	285.8392	....	....	21.1	7.7862	7.7920	....	....	
4	116.3412	0.9024	0.8908	22.4	7.7706	7.7767	7.7773	0.128579	
	116.3427	....	....	20.4	7.7721	7.7779	....	....	
6	79.2544	0.7436	0.7342	20.6	7.7940	7.7998	7.7990	0.128222	
	79.2530	....	....	22.6	7.7919	7.7983	....	....	

TABLE 5.—*Cylinders in the glass-hard state. Constants of the consecutive elementary shells. Second series of measurements.*

[1=6 cm. approximately.]

$R_0, \vartheta_0, \mu_0, \delta_0$.

No.	*R* observed.	*R* calculated.	ϑ observed.	ϑ calculated.	μ	δ observed.	δ calculated.	Remarks.
2								
4								
6								

First shell. $R_1, \vartheta_1, \mu_1, \delta_1$.

2	1.4987	1.4914	0.0225	0.0258	11.3757	7.862	7.847	
4	1.0051	1.0026	0.0164	0.0176	5.1922	7.795	7.795	
6	0.8786	0.8615	0.0266	0.0280	7.2370	7.849	7.847	

Second shell. $R_2, \vartheta_2, \mu_2, \delta_2$.

2	1.4676	1.4667	0.0226	0.0236	10.0908	7.736	7.746	
4	0.9829	0.9800	0.0282	0.0275	7.8777	7.756	7.756	
6	0.8483	0.8417	0.0330	0.0315	15.0378	7.818	7.832	

Third shell. $R_3, \vartheta_3, \mu_3, \delta_3$.

2	1.4410	1.4398	0.0298	0.0312	13.1437	7.746	7.748	
4	0.9506	0.9478	0.0362	0.0379	10.5044	7.765	7.766	
6	0.8096	0.8085	0.0437	0.0451	10.6801	7.810	7.810	

Fourth shell. $R_4, \vartheta_4, \mu_4, \delta_4$.

2	1.4130	1.4093	0.0259	0.0287	11.8224	7.762	7.765	
4	0.9175	0.9096	0.0308	0.0376	9.9776	7.741	7.748	
6	0.7656	0.7575	0.0440	0.0467	10.3845	7.794	7.794	

TABLE 4.—*Cylinders in the glass-hard state. Constants of the consecutive cores. Second series of measurements*—Continued.

$M_5, \rho_5, \Delta_5, \nabla_5$.

No.	M	ρ observed.	ρ calculated.	t	Δ_t	Δ	Mean Δ	Δ	Remarks.
2	270.2447	1.3635	1.3562	20.6	7.7899	7.7957	7.7953	0.128282	
	270.2450	....	....	22.0	7.7888	7.7949	....	....	
4	105.6781	0.8580	0.8489	20.1	7.7749	7.7805	7.7803	0.128529	
	105.6777	....	....	21.5	7.7741	7.7802	....	....	
6	69.1823	0.6888	0.6862	21.6	7.7898	7.7959	7.7956	0.128277	
	69.1831	....	....	20.3	7.7897	7.7953	....	....	

$M_6, \rho_6, \Delta_6, \nabla_6$.

2	255.7194	1.3244	1.3190	22.7	7.7910	7.7974	7.7973	0.128249	
	255.7207	....	....	20.8	7.7915	7.7973	....	....	
4	96.7900	0.8205	0.8122	21.5	7.7761	7.7822	7.7833	0.128480	
	96.7908	....	....	20.0	7.7789	7.7842	....	....	
6	60.3109	0.6492	0.6406	20.4	7.7913	7.7969	7.7963	0.128266	
	60.3108	....	....	21.7	7.7897	7.7958	....	....	

$M_7, \rho_7, \Delta_7, \nabla_7$.

2	244.6228	1.2962	1.2900	21.8	7.7928	7.7989	7.7990	0.128221	
	244.6207	....	....	23.2	7.7928	7.7992	....	....	
4	88.4153	0.7851	0.7762	21.0	7.7796	7.7854	7.7850	0.128452	
	88.4148	....	....	22.5	7.7783	7.7847	....	....	
6	52.0503	0.6062	0.5953	21.4	7.7863	7.7921	7.7928	0.128323	
	52.0498	....	....	22.6	7.7872	7.7936	....	....	

$M_8, \rho_8, \Delta_8, \nabla_8$.

2	226.9512	1.2512	1.2422	22.5	7.7958	7.8022	7.8022	0.128169	
	220.9500	....	....	24.4	7.7956	7.8022	....	....	
4	76.7934	0.7260	0.7241	21.7	7.7830	7.7891	7.7883	0.128397	
	76.7932	....	....	23.2	7.7812	7.7876	....	....	
6	42.5669	0.5486	0.5383	22.0	7.7882	7.7943	7.7935	0.128312	
	42.5664	....	....	23.4	7.7862	7.7926	....	....	

$M_9, \rho_9, \Delta_9, \nabla_9$.

2	205.7577	1.1946	1.1825	21.2	7.8009	7.8067	7.8064	0.128100	
	205.7554	....	....	23.0	7.7997	7.8061	....	....	
4	63.6639	0.6635	0.6584	10.7	7.7866	7.7922	7.7915	0.128345	
	63.6630	....	....	22.5	7.7846	7.7909	....	....	
6	31.9783	0.4729	0.4667	22.6	7.7814	7.7877	7.7875	0.128411	
	31.9793	....	....	20.0	7.7816	7.7872	....	....	

TABLE 5.—*Cylinders in the glass-hard state. Constants of the consecutive elementary shells. Second series of measurements*—Continued.

Fifth shell. R_5, ϑ_5, μ_5, δ_5.

No.	R observed.	R calculated.	ϑ observed.	ϑ calculated.	μ	δ observed.	δ calculated.	Remarks.
2	1.3817	1.3756	0.0366	0.0388	15.5908	7.737	7.741	
4	0.8802	0.8698	0.0444	0.0419	10.6641	7.748	7.748	
6	0.7162	0.7103	0.0548	0.0480	10.0710	7.820	7.823	

Sixth shell. R_6, ϑ_6, μ_6, δ_6.

2	1.3439	1.3376	0.0391	0.0372	14.5248	7.761	7.760	
4	0.8393	0.8305	0.0375	0.0367	13.3875	7.747	7.747	
6	0.6690	0.6634	0.0397	0.0456	8.8719	7.795	7.791	

Seventh shell. R_7, ϑ_7, μ_7, δ_7.

2	1.3103	1.3045	0.0283	0.0290	11.0983	7.758	7.756	
4	0.8028	0.7942	0.0355	0.0360	8.8754	7.765	7.766	
6	0.6276	0.6180	0.0430	0.0453	8.2606	7.821	7.819	

Eighth shell. R_8, ϑ_8, μ_8, δ_8.

2	1.2661	1.2661	0.0498	0.0478	17.6711	7.759	7.760	
4	0.7561	0.7501	0.0582	0.0521	11.6217	7.764	7.763	
6	0.5774	0.5668	0.0575	0.0570	9.4833	7.790	7.790	

Ninth shell. R_9, ϑ_9, μ_9, δ_9.

2	1.2228	1.2123	0.0566	0.0597	21.1041	7.758	7.762	
4	0.6958	0.6912	0.0635	0.0657	13.1298	7.772	7.778	
6	0.5108	0.5025	0.0758	0.0716	10.5879	7.813	7.812	

Resistance data.—The present results for specific resistance are merely preliminary. They show, however, that even in the case of steel rods one centimeter in diameter and of but a few hundred microhms total resistance, the electrical method may be successfully applied to the study of structural phenomena and made to yield good results. The reasons for this are at hand. The resistance effect due to changes of temper is enormously large as compared with the density effect. The interval hard-soft, when referred to the electrical scale, comprehends 300 per cent. of the resistance of soft steel; whereas the density effect is certainly smaller than 3 per cent. of the density of soft steel. The extreme sensitiveness of the resistance method is to some degree vitiated, however, by the fact that the electrical constants involve the dimensions of the rods; and very frequently right sections are not determinable within a few per cent. Moreover, in case of resistances as small as those mentioned, the electrical measurement itself must be made with caution, and the error will under all circumstances amount to 1 or 2 per cent. None of these difficulties enter into a determination of the density effect; but in spite of the objections specified, the large range of electrical variation renders the resistance method certainly as accurate as the density method. It will be invaluable for the investigation of slow changes of strain; such, for instance, as would result if the stress in the interior parts were essentially conditioned by the stress at the exterior or superficial parts of a tempered steel rod (see Shrinkage, p. 41). In this case the necessary results depend on purely electrical data only. The two methods are admirably complementary, for the resistance method begins to yield satisfactorily reliable data at the very stage of thickness of rod where the density method shows insufficient sensitiveness, and conversely.

The resistance method has a further advantage: the errors due to hard ends (see p. 31) may be wholly and conveniently eliminated. For if these comparatively thin rods be inserted in the dissolving cell already described, it is only necessary to slide a piece of rubber hose over the ends to confine the solution to as small a part of the equatorial regions of the rod as may be desired. Moreover, thickness may be reduced with some uniformity throughout the chosen lengths, even as far as 0.1^{cm} of diameter. In the annexed diagram (Fig. 5) one of these rods, from which seven successive layers have been removed, is drawn full size. During solution the parts *a a* are covered with rubber, as has been stated.

FIG. 5. Rod No. 11, after removal of seven shells.

To hold the rods during the resistance measurement, we devised the special form of clamp shown in the annexed diagram (Fig. 6). *A A* is a block of oiled wood, through the middle of which passes an iron bolt *cd*, carrying a steel cross-piece, *ef*, both ends of which are conical. Attached to the ends of the block *A A* are two thick strips of hard rubber or of metal, *ab ab*, carrying steel screws, *mn mn*, the points, *n n* of which are also conical. The rods *ne fn* are tested in pairs, and secured by aid of conical depressions in their end surfaces, between the sharp ends of the screws *mn mn* and the ends of the cross-piece *ef*, as shown in the figure. At *m m* copper terminals have been soldered into the heads of the steel screws, through which the line of metal *mn ef nm* is inserted with a standard into one branch of the bridge, the other being the calibrated wire. From four brass clamps, *r r r r*, copper wires pass tensely around the respective steel rods *ne fn*, and thence (alternately) through galvanometer to sliding contact. The method of measurement is that of Matthiessen-Hockin.

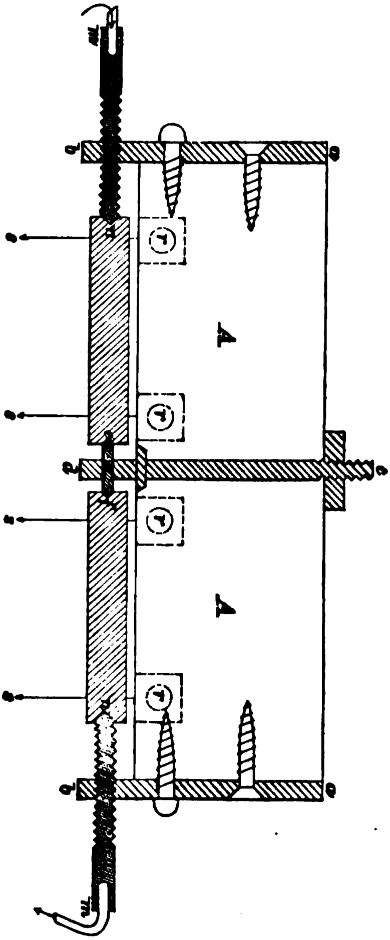

FIG. 6. Holder for resistance measurements.

The experimental data obtained in the way described are given in Tables 6 to 8. In Table 6 (Rod No. 3), column one contains the number of the core from which the resistance W_t, at $t°$, for the effective length, l, and the radius ρ are derived. The column S_0 gives the corresponding specific resistance, at 0°, for the rod in a condition of either rough or smooth surface (trued with diamond), as specified.

TABLE 6.—*Resistance constants* (*No.* 3).

No.	W_t	t	l	ρ	S_0	
Core 11	333	19	4.95	0.4182	35.7	
Core 12	386	17	4.90	......	34.3	Rough.
	349	17	4.45	0.3771	33.8	Smooth.
Core 13	484	20	4.92	......	33.5	Rough.
	461	20	4.52	0.3354	34.7	Smooth.
Core 14	674	27	4.65	0.2850	35.3	Smooth.

The values for S_0 being certainly affected with an error of, say, 3 per cent., must be regarded as coincident. They merely show that after the removal of 14 shells the variations of the hardness of No. 3 occur within narrow limits. Moreover, the absolute value of S_0 is small, indicating either a poor quality of steel, or, more probably, that the strata of large resistance have been removed.

Similar results, but more complete, are given in Table 7. The nomenclature is the same as that used above. S_t, the specific resistance of consecutive cores at t°, is reduced to the values for 0°, by aid of the temperature coefficient, α. R, ϑ, s denote the mean radius, thickness, and specific resistance, respectively, of the shells. We have, therefore,

$$R_n = \tfrac{1}{2}(\rho_{n-1} + \rho_n) \qquad \vartheta_n = \rho_{n-1} - \rho_n \qquad s_n = \frac{q_n}{Q_{n-1}\Lambda_{n-1} - Q_n\Lambda_n}$$

when Q and Λ are symbols of section and conductivity, respectively, and $q_n = Q_{n-1} - Q_n$.

TABLE 7.—*Stubs's bright steel. Resistance constants of the consecutive cores and shells. Rods tempered glass-hard.*

[$l = 6$ cm. approximately.].

No.	Shell.	W_t	ρ	t	S_t	α	S_0	R	ϑ	s
		Microhm.	*Cm.*	°*C.*	*Microhm.*		*Microhm.*	*Cm.*	*Cm.*	*Microhm.*
11	0.........	660	0.318	19	42.7	0.0017	41.4	....	....	....
	1.........	820	0.294	20	45.4	16	44.1	0.306	0.0240	31
	2.........	1,000	0.262	22	45.4	16	44.0	0.278	0.0318	46
	3.........	1,290	0.227	18	44.5	17	43.2	0.244	0.0349	45
	4.........	2,250	0.167	20	45.1	16	43.8	0.197	0.0599	43
	5.........	4,130	0.130	21	47.7	15	46.3	0.149	0.0367	39
	6.........	6,620	0.103	21	48.0	15	46.6	0.117	0.0273	46
	7.........	16,110 15,970	0.069 0.070	24 22	52.5 56.4	15 14	50.9 54.8	0.086 0.087	0.0338 0.0331	44 41
12	0.........	680	0.318	19	43.1	0.0017	41.8	....	....	....
	1.........	820	0.296	20	44.0	17	42.6	0.307	0.0215	37
	2.........	1,020	0.262	22	44.2	17	42.7	0.279	0.0337	43
	3.........	1,300	0.235	18	45.5	16	44.3	0.249	0.0270	37
	4.........	2,440	0.182	20	47.3	15	46.0	0.208	0.0533	42
	5.........	3,390	0.148	21	47.0	15	45.7	0.165	0.0337	47
	6.........	5,400	0.114	21	45.8	16	44.4	0.131	0.0336	47
	7.........	11,950 9,520	0.089 0.088	24 22	67.1 51.6	15 16	64.9 49.9	0.102 0.101	0.0253 0.0266	*30 38
	8.........	22,640	0.059	23	52.5	16	50.8	0.073	0.0291	49
13	0.........	660	0.318	19	41.8	0.0017	40.4	....	....	....
	1.........	730	0.304	21	43.4	17	42.0	0.311	0.0140	30
	2.........	800	0.288	20	43.8	17	42.4	0.296	0.0158	38
	3.........	910	0.267	18	44.2	17	43.0	0.278	0.0204	39
	4.........	1,310	0.223	20	45.0	16	43.7	0.245	0.0442	41
	5.........	2,110	0.179	21	45.4	16	44.0	0.201	0.0444	43
	6.........	3,200	0.149	20	47.0	15	45.8	0.164	0.0297	41
	7.........	8,830	0.092	23	48.5	15	47.0	0.120	0.0574	45

TABLE No. 7.—*Stubs's bright steel. Resistance constants of the consecutive cores and shells. Rods tempered glass-hard*— Continued.

No.	Shell.	W	ρ	t	S	α	S_0	R	δ	s
		Microhm.	*Cm.*	°C.	*Michrom.*		*Michrom.*	*Cm.*	*Cm.*	*Michrom.*
14	0.........	680	0.318	19	42.6	0.0017	41.4	....	....	....
	1.........	740	0.304	21	43.4	17	42.0	0.311	0.0134	36
	2.........	1,090	0.289	20	56.2	14	54.8	(0.297)	(0.0155)	(*a*)
	3.........	960	0.269	18	44.0	17	42.7	0.287	0.0350	39
	4........	1,360	0.227	20	44.8	16	41.9	0.248	0.0422	45
	5.........	1,990	0.189	21	46.3	16	44.9	0.208	0.0382	30
	6.........	2,930	0.158	20	48.4	15	47.0	0.173	0.0309	40
	7.........	5,710	0.106	23	44.5	17	42.9	0.132	0.0517	51
	8....	21,280	0.062	23	55.5	14	53.9	0.084	0.0444	39

a Bad contact.

Some of the results (see Nos. 11 and 12, shell 7; No. 14, shell 2) which it was found necessary to repeat show how exceedingly important it is to secure excellence of contact throughout the bridge adjustments. In repeating the experiments we should temper rods 20^{cm} long, solder the ends to copper terminals, and remove only equatorial parts of shell. We may remark that the sectional error is here probably positive and relatively large for small values of section. This introduces a very serious element of uncertainty into the results. s is only to be regarded as a check on S_0.

Table 8, finally, contains direct tests for shrinkage. ρ being the radius of the core, W_t denotes the resistance before and after the lapse of the number of hours given under h. If shrinkage is an actual occurrence, it must be a phenomenon of viscosity; and hence the observed effect would vary gradually through infinite time. The differences of W_t, in Table 8, however, are mere errors of observation.

TABLE 8.—*Resistance tests for shrinkage.*

No.	Date.	h	ρ	W_t	Remarks.
5	....	......	0.318	....	Original radius.
5	November 19, 1885	0	0.30	1,030	One shell off.
	November 20, 1885	15	....	1,022	
5	November 20, 1885	0	0.20	1,803	Two shells off.
	November 21, 1885	21	.. ....	1,803	

DISCUSSION.

True and apparent structure.—In Bulletin 14 we defined structure (p. 113, *note*) as the law of variation of density encountered on a passage along any radius of the rod, from axis to circumference. But a mere glance at the above tables shows that we must obtain greater uniformity of results if we reverse the order of progress and follow variations of density from the surface normally *inward.* Let depth, taken positive in the direction from surface to axis, be denoted by x. Then the above tables enable us to construct

$$\delta = F(x) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where F is a symbol of functionality and δ the apparent density at a distance x below the surface. δ is an approximate expression for the structure of the rod. To pass from this $F(x)$ to the true structure, it is necessary to make allowance for the fact that in any given uniformly tempered cylinder the elementary coaxial shells are not homogeneous in the axial direction; that they increase in density as we pass from median plane toward the ends of the cylinder. More succinctly: In view of the relatively small length ($2l_0$) of the cylinders as compared with their diameters ($2\rho_0$), the available method of tempering necessarily imparts to them a box-within-box structure. Hence, it follows that

$$l_0 F(x) = (l_0 - x) f(x) + \int_0^x f(x)\, dx \quad \ldots\ldots\ldots\ldots\ldots (2)$$

By differentiating, simplifying, and again integrating, this equation leads to an elegant expression for true structure, $f(x)$, in terms of apparent structure, δ:

$$f(x) = l_0 \int \frac{F'(x)}{l_0 - x}\, dx = l_0 \int \frac{\delta'}{l_0 - x}\, dx \quad \ldots\ldots\ldots\ldots\ldots (3)$$

$f(x)$ being the density at a point anywhere within the cylinder at the distance x normally below the surface.

With equation (3) in hand, it is then easy to investigate corresponding expressions for Δ, the mean density of successive cores, in terms of $f(x)$ and x. These, however, appear under involved forms. They throw no new light on the discussion, and therefore are omitted.

Density, Δ, of successive cores.—To digest the data in the above tables we shall first examine the relations of Δ, the mean density of core; and then from these introductory results proceed with the discussion of structure proper.

In Figure 7 we have constructed the various results of Tables 1, 2, 4, by representing Δ as a function of radius. The loci for the data of cylinders Nos. 1, 2, 3, 4, all of which hold for steel of the same kind, are similar in their general character. This becomes very clear if we pass from the surface in the direction of negative ρ toward the axis. After removing superficial shells, Δ appreciably falls in all cases to a pronounced minimum. It then increases at approximately the same rate for each cylinder and in a direction which if indefinitely prolonged would trend toward the diagrammatic position of "soft" (not easily introduced into the figure). The chief features of these curves are therefore the minima, their approximate parallelism, their apparently linear contour, their independence of radius. Having obtained these results we were inclined to look for similar variations in all other kinds of steel.

Not a little startled were we, therefore, by the data for No. 6, which show an almost complete inversion of the structural character of the earlier rods. In the cases of Nos. 1 to 4, Δ increases from the circumference inward; in the case of No. 6, Δ continually decreases, indeed at almost the same rate. It is therefore clear that structure must be radically conditioned by the *quality* of the steel carrying temper. In other words, to discriminate between different kinds of steel by structure ($(f(x))$) data, our classification would show immediate relations to the power for retaining stress heretofore postulated.[1]

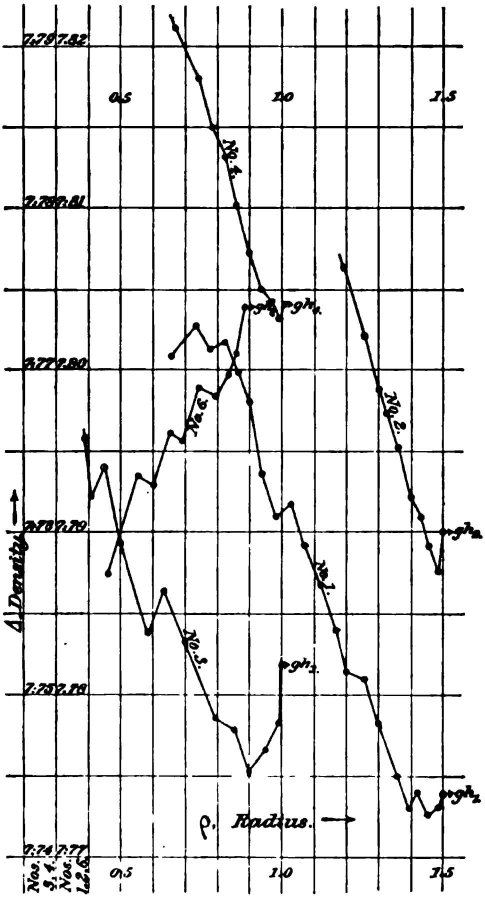

FIG. 7. Density as a function of radius.

The superficial minimum or corresponding point in No. 6, occurring as it does generally, is an observation of some importance. It probably marks the depth of layer below which the combined processes of diffusion and oxidation no longer remove carbon from steel. This depth will of course depend on the time of exposure to high temperature before quenching. The observation in question is confirmed by this experimental result: if rods be heated very intensely (Nos. 1 and 3, incipient white heat), the superficial layers are frequently so soft as to yield readily to steel master tools. Moreover in No. 1, which was twice quenched, this shell is comparatively thick. The underlying core is always very hard, and it is thus possible to arrive at the thickness of the soft shell with some accuracy. It does not extend inward as far as the minimum; but this does not tend to invalidate the remarks just made, because softness, after quenching, must correspond to an extreme degree of decarburation. There is, however, one point of view from which the minimum acquires greater significance than a secondary or incidental result. If the rod subjected to sudden cooling be sufficiently thick, it is obvious that the interior will remain soft. Hence the march of Δ toward smaller values, exhibited by No. 6, cannot keep on indefinitely. Δ must pass through a minimum and then again increase. Hence we infer that the position of this minimum bears some inherent relation to the quality of the steel under observation — that its depth will increase in proportion as the intensity of strain which the rod can carry without rupture, increases. Further experiments are necessary to decide this question.

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[1] U. S. Geol. Surv. Bull. 14, p. 95.

It is curious to note that the glass-hard Δ of longitudinally cracked rods (Nos. 3 and 5) is smaller than that of rods of unbroken surface. This difference may be an expression for the intensity of stress lost in consequence of rupture. More probably it is an effect of thickness.

In the case of No. 1 structure has been studied throughout an interval of almost one centimeter of depth. But it is not until we reach the lowest layers for this depth that the curve manifests any tendency to change its character. And even here the evidence is uncertain, both because the density measurements of the comparatively thin rod are no longer so accurate and because the effect of hard ends, to which we adverted in the preceding paragraph, becomes more and more seriously appreciable as radius decreases. The singularly simple and suggestive curves are therefore in striking contrast with the necessarily complex considerations which must enter into their interpretation. If the cylinder be originally given of length $2l_0$ and of diameter $2\rho_0$, and if then a shell of thickness x be removed, careful inspection of the core will enable us to distingush the following three parts: (1) The central cylinder bounded by mantle (radius $\rho_0—x$) and two normal planes at a distance $l_0—\rho_0$ and $—(l_0-\rho_0)$ from the equator. Within this partial cylinder δ varies from $f\,(\rho_0)$ to $f\,(x)$ in the direction of radius, symmetrically with respect to axis. (2) The two end cylinders bounded by mantle and by normal planes, l_0 and $l_0—x$, $—l_0$, and $—(l_0—x)$, respectively, from the equator. Here δ changes from $f\,(x)$ to $f\,(o)$ in the direction of axis, symmetrically with respect to equator. (3) The two intermediate partial cylinders bounded by mantle and normal planes, $l_0 - \rho_0$ and $l_0 - x$, $-(l_0 - \rho_0)$, and $-(l_0 - x)$. It is here that the variation of δ is involved. To represent it approximately in the right partial cylinder, let a cone be described around a given axis, upon the basal plane $l_0 - x$, with its vertex at a distance $l_0 - \rho_0$ from the equator. This cone divides the said partial cylinder into parts such that in the re-entrant figure, δ varies from $f(\rho_0)$ to $f(x)$ in the direction of radius, symmetrically with respect to axis. In the simple conical figure, δ varies from $f(\rho_0)$ to $f(x)$ in the direction of axis, symmetrically with respect to equator. In view of these annoying complications, it is expedient to calculate δ from successive values of Δ. This may be done without any auxiliary hypothesis at all. Having given δ we arrive at the true structure as shown in the preceding paragraph.

These remarks show that to obtain perspicuous values for Δ it is advisable to use only the equatorial parts for measurement; that is, to remove the ends completely either by solution or by suitable mechanical means before commencing the structure-measurements proper.

Density, δ, of successive shells.—In our endeavor to construct the relation between the density δ (apparent structure) and the mean radius of shell, R, we must necessarily be guided by the following consideration: If the shell be thin and contain no maximum or other singular point, then the observed δ is approximately a point on the locus sought; but if the shell, however thin, contain one or more maxima, then the observed δ need not be a point on the locus at all, and the discrepancies and the liability to errors of interpretation will increase as the maxima become more and more sharp and crowded. Let the shell be so thin that its outer and its inner radius are practically identical with its mean radius, i. e., that the right section does not differ appreciably from $2\pi R\, dR = 2\pi R \vartheta$, in area. In this case $2\pi R \vartheta \delta$ is the mean mass per unit of length of shell; and hence any elementary contour which, between $R - \vartheta/2$ and $R + \vartheta/2$ incloses the same area as $\vartheta\delta$, may be taken as a boundary of the part of the curve under examination. This shows at once the nature of the difficulties encountered in endeavoring to discuss the present observations on structure. It opens a field for speculation so wide as to be thoroughly unsafe. We will, therefore, in the sequel, limit ourselves to right line diagrams, to mere linear combinations of the points given by experiment. We thus exhibit the results, as far as possible, unaffected by any fantasy of our own.

In Fig. 8 the values for δ are represented as functions of R, on a scale in correspondence with the smaller accuracy of the present set of data. The scale is, moreover, such as enables us to insert the interval hard-soft for each curve. Restricting our comparison to Nos. 1 to 4 for the present, we find at first sight that the variations are jagged and apparently irregular and confused. It is, therefore, well to confine the discussion still further; to examine the data holding for No. 1, for which cylinder the observations are most nearly complete; then to use the other curves as a means of corroborating and of further elucidating the divers inferences drawn.

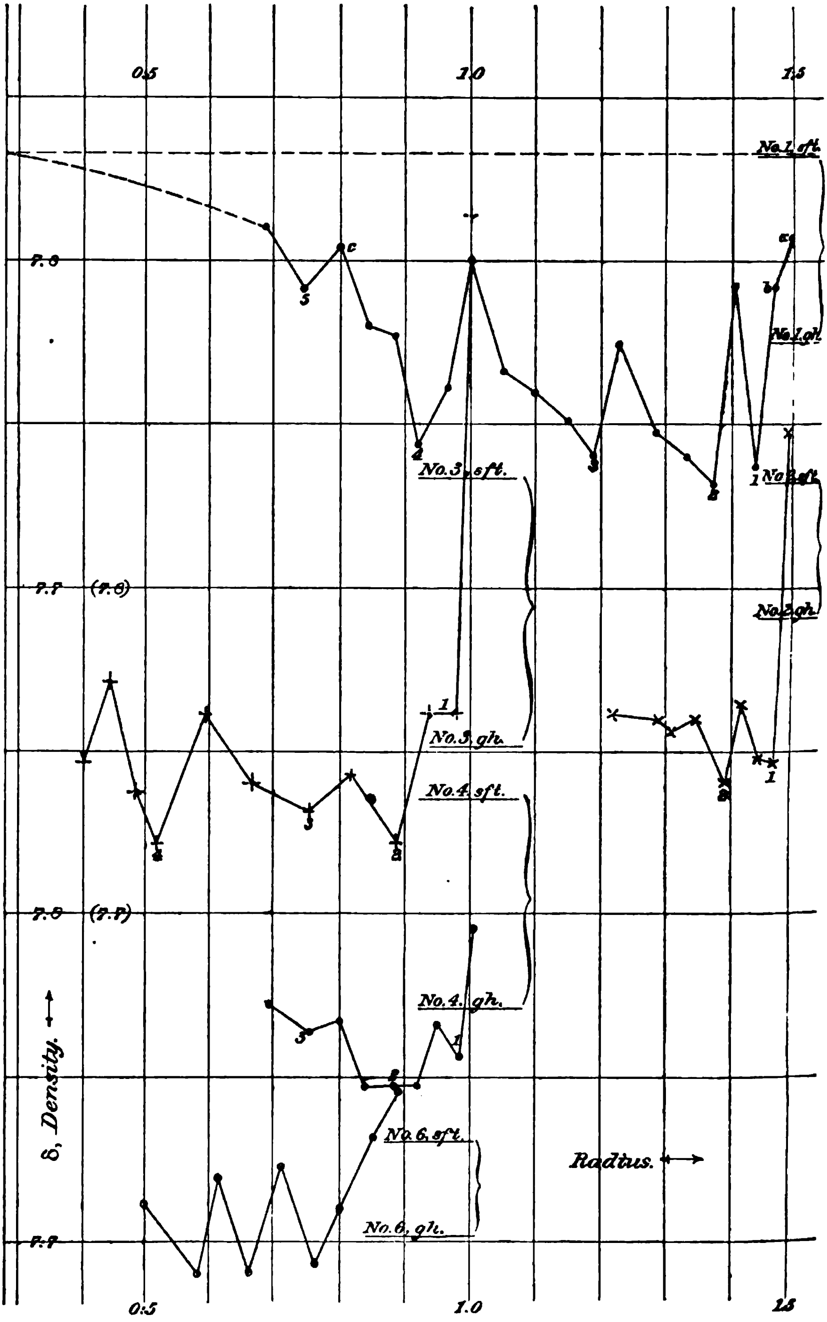

Fig. 8. Elementary density as a function of radius.

Inasmuch as the evidence given by No. 1 is fully valid (see discussion under Errors, p. 43), as we pass from the circumference inward δ varies in accordance with an obviously harmonic law. We readily discern five pronounced periods (all marked in the diagram), which are crowded near the surface, but which lengthen and are gradually obscured as we pass toward the axis. During this oscillatory march, δ increases from values which lie below the glass-hard density almost as far as the density of the soft state. In other words, the interval of variation of density studied from point to point of a tempered rod is fully twice as large as the density interval hard-soft. Indeed, if we take into consideration that δ is only the apparent structure, that the shells are not longitudinally homogeneous, but hard at the ends, it appears altogether probable that the density of soft steel will actually be reached. At the same time, it must be borne in mind that the density at about 0.7^{cm} below the surface does not differ appreciably from the mean density of the core. Hence we infer fairly that from here on, inward, large fluctuations of δ will no longer occur.

The inquiry next in importance is the relation of density at any point within the cylinder to the hardness there mechanically observed. To the occurrence of soft strata between the points marked *a* and *b* we have already adverted. But below this the steel appears exceptionally hard—so hard that the little ridges and furrows left on the surface by the diamond readily grind off the edges of a file or any other hard steel tool. This state of hard temper continues until we reach the points in the vicinity of *c* in the diagram, say 0.7^{cm} below the surface. From here on the rod is quite appreciably filable near its equatorial parts, the ends, of course, retaining the intensity of hardness of the superficial shell.

After these remarks it is in place to pass in review the corroborative evidence obtained from the other cylinders. In no case is the periodicity so sharply pronounced, and were the data for Nos. 2, 3, 4 alone available it would escape detection. But the evidence by no means conflicts with the inferences adduced for No. 1. No. 2, for instance, shows the first and second minima (see diagram) in proper position. The inclosed maximum is not so distinctly marked. No. 2, however, was quenched from a temperature much below that of No. 1; and since the harmonic distribution of density is primarily a mechanical phenomenon, the importance of temperature is at once obvious. For similar reasons the periods of No. 4 are more obscure than those of No. 3. In all rods (Nos. 1 to 4) the first minimum is unmistakably located near 0.05^{cm} of depth. The second minimum falls between 0.10^{cm} and 0.15^{cm} of depth; the third minimum in the three observed cases between 0.25^{cm} and 0.30^{cm}; the fourth minimum between 0.5^{cm} and 0.6^{cm} of depth. This accordance is too persistent to suggest mere chance coincidences.

Thoroughly distinct from these curves is the locus of the set of values for No. 6. The variations show almost simple periodicity around the glass-hard line as a position of equilibrium. A comparison of the curve

No. 6 with the curve Nos. 1 to 4 at once calls to mind the differences in the qualities of the steel used. Similarly to Nos. 2 and 3 we here find the density of external shell decidedly above that of the soft state. The material is probably poorly carburized; for even in the glass-hard state, hardness (mechanical) is not intense.

Having described the principal features of the phenomenon of structure somewhat minutely, it will be our next endeavor to account for the remarkable variations observed, at least in some provisional way. The methods which suggest themselves to us may be grouped in reference to two general heads, periodicity and carburation. But there are two ways of explaining periodicity: we may regard it as a real structural phenomenon, or we may regard it as a secondary occurrence, bearing no inherent relation to temper at all and due to intermittent shrinkage of the cylinder while in the hands of the operator. It is expedient to consider these questions in separate paragraphs.

Possibility of harmonic distribution of density.—Suppose we ignore the occurrence of periodicity for a moment and consider only the mean ascent of the loci for δ. Then in case of steel of a given kind, subjected to a given operation of tempering, the hardness or density exhibited by any point is essentially dependent on the position of the said point below the surface, as our data show. The rate at which the point cools is similarly conditioned. Hence it is natural to associate the first phenomenon with the second, and to state that the hardness in a given point is a function of the rate at which cooling there takes place. Knowing the relative rates of cooling of consecutive shells we would have given us therewith a method for expressing hardness (estimated in units either of density or of resistance) in terms of rate of cooling. But the adequacy of such a mode of inquiry is incomplete, because the shells in question are parts of the whole, and not distinct individuals. The consideration simply suggests the cause for the gradual decrease of hardness from surface to axis.

Returning from this digression to the consideration of periodicity proper, we remark that solids, when subjected to shearing strains, usually exhibit low degrees of elasticity and experience marked changes of form. But all substances, whether solid, plastic, viscous, or liquid, when subjected to pure isotropic strains—in the present instance to a strain of compression equally distributed in the three cardinal directions—are probably very nearly perfectly elastic. Here, therefore, is a principle suggesting the possibility of vibratory movement, even in an intensely heated viscous solid. Suppose now there be given a small sphere of steel. Let this be heated above redness and then suddenly cooled (quenched) uniformly over the whole surface. Then we contend that it is not probable that during the initial stages of cooling contraction should manifest itself as a simple, aperiodic, static phenomenon.[1]

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[1] Attention must here be drawn to to the Cumming-Gore phenomenon of sudden contraction at red heat. Cf. U. S. Geol. Surv. Bull. 14, p. 99.

We contend, in other words, that in consequence of sudden and enormous compression, virtually applied at the surface, the whole sphere during incipient cooling will be thrown into a state of vibration symmetrical with respect to the center of figure. Under the ideally perfect circumstances of quenching, therefore, the sphere must so vibrate that all points of any given spherical shell at a given time are in like phases of oscillation. It follows obviously, moreover, that in the case of a long cylinder suddenly and uniformly cooled, the phases of the elementary coaxial shells will, at a given time, be identical.

The necessary concomitant of the vibration specified is harmonic distribution of density; and the maxima and minima encountered may be made to differ by amounts as large as we please, up to a certain limit, by increasing the temperature from which cooling takes place. But while vibration is in progress the cylinder itself is cooling rapidly, or, in other words, the rigid shell closes inward from surface to center, *congealing*, as it were, and retaining permanently within itself the traces of the harmonic distribution of density in question.

More concisely: Let the sphere be of large radius. Then the density in a point at a normal distance, x, below the surface, at the time t, during the initial stages of cooling may be expressed by

$$\delta = a \sin \frac{2\pi}{\lambda}\left(vt - x + A\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where v is the velocity of propagation, λ the wave length, A a length phase.

Let

$$x = \varphi(t)\,;\ t = \psi(x) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

express the depth of the advancing inward boundary of the rigid shell[1] at the time t. Then the mathematical effect of congealing may be said to be equivalent to an *elimination* of t between equations (1) and (2); so that for the rigid sphere,

$$\delta = a \sin \frac{2\pi}{\lambda}\left(v\psi(x) - x + A\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

a function of x only, applies. Equation (3) shows that the wave actually congealed need be identical in regard to neither phase nor wave length with the original wave λ; that it will generally be very much larger. For instance, under the simplified conditions that $x = \varphi(t) = m + nt$, if we put

$$\text{arc ctg } n = \alpha \qquad\qquad \text{arc ctg } v = \beta$$

the congealed wave will exhibit the new phase A_1', and new wave length, Λ,

$$A' = A - m \text{ and } \Lambda = \lambda \frac{\sin \beta}{\sin(\beta - \alpha)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

respectively. According as α lies anywhere between $\beta - \frac{\pi}{2}$ and β, Λ may have any value between the limits $\lambda \sin \beta$ and ∞. But it is essentially constant, and the periodicity uniform. Here we may remark in passing, that if shells of like thickness be etched off, the observed harmonic law will bear some such relation to the congealed periodicity as is expressed in equation (4).

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[1] Rigidity may here be the result of chemical as well as of mechanical action (temperature). See p. 42.

If $\varphi(t)$ be not linear but represent some more complex function, as it must in the case under consideration, A must also vary continuously. If, furthermore, $n = d\,\varphi(t) \mid dt$, and if n decrease continuously, then A will increase with x wherever $n > v$; it will decrease with increasing x wherever $n < v$. The former of these criteria seems to be given by the diagram, Fig. 8; but it must be borne in mind that the curves there given are seriously distorted by other causes. The inference goes no further than to point out that the harmonic distribution of density must be of variable period; and that this variation will depend on the relative values of rate of wave propagation and rate of advancing rigidity.

As the process of cooling proceeds, the continually increasing thickness of rigid shell interferes with vibration in a way to obscure the periods more and more, as we pass from the surface inward. Within the shell the energy of vibration is largely potentialized. We have already pointed out that in the case of cylindrical figure true structure is related to the apparent structure, δ, by the equation

$$f(x) = l_0 \int \frac{F'(x)}{l_0 - x}.$$

If $F(x)$ be harmonic, $f(x)$ will also be, with this limitation, however, that $f(x)$ and $F(x)$ cannot, at the same time, both be uniformly so. Probably neither will be; and we have a second condition for the variable periodicity observed. The effect of superficial decarburation on δ is a third condition.

Perfect uniformity of sudden cooling or quenching is not practically attainable. Pressure is first applied at the parts of the hot cylinder which first touch the cold water, and it is not until the mass is fully submerged that the temperature, &c., of the surrounding medium is fairly uniform. Again, certain parts of the quenched body will always be more favorably placed in regard to contact with cold water than others. Hence the conditions are such that perfectly symmetrical arrangement of the parts of like given density relatively to the axis and center of figure of the steel body must be a very rare occurrence. True structure is therefore more or less fully obscured by the divers adventitious circumstances of chilling and by intentional or accidental variations in the operation of tempering itself.

The views here set forth are very well illustrated by the following little experiment: Let a ring capable of up and down motion be suspended with its plane always horizontal over a basin of water. If now the ring be lowered at regular intervals so as to dip into the water with all its parts at once, and if the period of oscillation of the ring be adjusted synchronously with the oscillation of the circular wave under it, the whole surface of the water bounded by the ring may be made the field of regular and continued wave motion. Suppose now the water to congeal from the ring inward at some regular rate, then the congealed surface will show uniform periodicity, which will not, however, be identical with the period of the liquid surface. If the rate of advance be variable, the periodicity must be variable. Finally the conditions of practical quenching may be typified by the interferences resulting if the ring be dipped obliquely relative to the surface of the water.

Intermittent shrinkage.—Whatever the mechanical structure of steel is, it may be reasonably argued that the conditions of equilibrium at every point are in conformity with and influenced by the dimensions of the bar. Hence, if parts of the rod be removed, by solution or otherwise, we may look for an excess of stress in those parts; and if the process of removal be often repeated, this excess may eventually increase to an intensity sufficient to effect a permanent and sudden change of strain. A series of such changes would constitute the intermittent phenomenon in question.

Glass-hard steel is under a strain of dilatation. The probable effect of the removal of superficial coats is, therefore, contraction. We need only suppose that the greater part of such contraction takes place uniformly, in proportion as shell is being removed, to obtain the principal features of Fig. 7, Nos. 1 to 4; moreover, that sudden contractions of higher order, occurring intermittently for the reasons specified, are superimposed upon this main and uniform shrinkage to generate Fig. 8, Nos. 1 to 4. For since

$$\delta = \frac{\frac{\mu}{M_1}}{\frac{M_0}{M_1}\nabla_0 - \nabla_1} \text{ and } d\,\delta = \frac{\frac{\mu}{M_1}\,d\,\nabla_1}{\left(\frac{M_0}{M_1}\nabla_0 - \nabla_1\right)^2},$$

and since we may consider μ, M_0, M_1, ∇_0 constant in any given experimental case, it is obvious that if ∇_1 vary by small decrements, in consequence of contraction, δ will vary by corresponding decrements, and conversely. If, therefore, we examine Fig. 8, No. 1, for instance, sudden contraction may have occurred between *b* and the first minimum, between the first maximum and the second minimum, between the second maximum and the third minimum, between the third maximum and the fourth minimum, and so on. Between any minimum and the next consecutive maximum we have usually a curve of gradual ascent, indicating normal changes of density.

Some evidence of contraction is contained in the above tables, and discussed under Errors, p. 48; but it is insufficient. On the other hand, no contraction could be discerned by resistance measurements at all (p. 31). The occurrence of shrinkage is, therefore, questionable, and more searching investigation may show it to be absent. Moreover, it would furnish no satisfactory explanation for certain degrees of likeness in the curves Nos. 1 to 4, to which we have already referred. After the removal of nearly 1^{cm} of shell, hardness is still retained at the ends of No. 1, whereas it gradually vanishes near the middle parts. This, again, is adverse to the shrinkage hypothesis.

Carburation.—The probability of absence of true shrinkage to which we referred in the last paragraph, taken in connection with the great molecular stability of the shells in the divers specimens of steel examined, suggests that the intensity of the mechanical strain of glass-hard steel may possibly be overestimated. Mere superficial scratching is frequently sufficient to explode a Rupert's drop.[1] Glass-hard steel, on the other hand, may be reduced in thickness to quite one-third the original diameter, or again, thin rods (0.7^{cm}) reduced to mere filaments without showing any thoroughly satisfactory evidence of shrinkage. In all the experiments made by the resistance method, hardness is found to increase very perceptibly from surface to core; the (thin) rods (radius $= 0.3^{cm}$) are hardest at the axis. If, therefore, steel has once been subjected to an operation capable of evoking the strain of dilatation in question, the strain imparted appears to possess a certain permanence of character and to be able to maintain itself independently of the presence or thickness of the surrounding layers. In this respect it is peculiar. It yields readily to temperature only; and we infer that it owes its persistency to molecular or chemical agencies.[2] Suppose, therefore, that with the carbon available in steel it is possible under favorable circumstances to produce a variety of iron-carburets; in other words, that under favorable variation of circumstances, a certain latitude of density is a possible occurrence. Then we argue, plausibly, we think, that during the process of sudden cooling of steel from red heat the carbon and iron at any point within the body will unite (for the given degree of carburation) in correspondence and conformity with the intensity of strain there experienced; that, therefore, in the cold steel the strains are to a large extent permanent and independent of the condition of stress of the surrounding medium of steel.

The remarks just made will have shown how incomplete our knowledge of the phenomenon of structure as yet is, and where further experimentation is essential. The paragraph on periodicity postulates certain relations between velocity of wave propagation and rate at which rigidity advances inward. The occurrence of shrinkage is hypothetical and lacks satisfactory evidence; nor has direct quantitative measurement been brought to bear on the conditions of carburation.

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[1] Our recent experiments show that the respective behaviors of steel and Rupert drops here in question are identical.—*August*, 1886.

[2] Conditions favorable to chemical combination (quenching), so difficult of attainment in case of low degrees of carburation (steel), are given at once in case of greater carburation (cast-iron), where mere cooling in air will harden. The mass of available carbon is therefore here an essential factor and the phenomenon in hand is probably an instance of mass action.

Nevertheless we believe that cautious blending of the three views advanced will reconstruct the actual phenomenon of structure as accurately as the data now in hand describe it.

Resistance.—The results in Table 7 show no pronounced periodicity. Considered individually, moreover, they would not be of much value. Considered as a whole they mutually sustain each other, and indicate a decided increase of resistance in passing from surface to core. Hardness increases rapidly inward, and this quality here exists in greatest intensity at the axis. These rods therefore show like behavior with No. 6, and the general structure is that of relatively dense external layers surrounding a relatively rare core. But it must be borne in mind that these rods are comparatively thin; that for greater thicknesses the loci will probably pass through minima of Δ or maxima of S_0 and of hardness, thereupon to enter into a second phase of variation, such as is exhibited by the Δ of rods Nos. 1 to 4. Considered in this light, the minima in Fig. 7, Nos. 1 to 4, are to some extent critical points, inasmuch as their position varies in depth with the quality of steel employed, and is deepest for steel capable of withstanding a maximum of stress of the given kind.

Finally, it is well to remark that the data of the above tables, when interpreted in the manner given under carburation, conflict with received physical notions of temper and structure; for it appears that the equilibrium of stress at any point is maintained independently of the presence or absence of other layers. Hence, the deduction made in Bulletin 14, page 103, from data obtained with malleable cast iron, viz, that the electrical variations accompanying temper are evoked by strain, and are only to a smaller extent dependent on the conditions of carburation, does not follow in the way in which we there understand it.[1] In short, the present results make it questionable whether in the *cold* rod the effects due to strain and to carburation, respectively, can be sharply distinguished at all (cf. p. 42).

Errors.—In the present research some of the inferences are dependent on variations of the descriptive function, δ, the order of which is not much above the aggregated effect of errors of observation. Hence a full enumeration of the divers sources of discrepancy, together with an analysis of the magnitude and distribution of their respective influences, is a matter of cardinal importance.

It seems expedient to commence with the observations proper, since it is here feasible to obtain good estimates for the amount of distortion probable in each case. If we define δ_n, the density of the nth elementary shell, approximately by

$$\delta_n = \Delta_{n-1} - \frac{R_n}{2\vartheta_n}(\Delta_{n-1} - \Delta_n) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

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[1] Probably in malleable cast iron insufficient quantities of transmutable carbon are available, the metal being rich in graphite. The presence of neutral conducting substances obscures the electrical effect of temper.

we may regard the errors of δ_n essentially conditioned by the values and variations of R, ϑ, $\Delta_{n-1}-\Delta_n$. The range of variation of these quantities has been

$$0.5 < R < 1.5 \quad \ldots \ldots \tag{2}$$

$$0.01 < \vartheta < 0.1 \quad \ldots \ldots \tag{3}$$

$$0.0010 < \Delta_{n-1}-\Delta_n < 0.0050 \quad \ldots \ldots \tag{4}$$

Hence, if to prevent confusion of signs we designate errors by prefixing the differential symbol "d," we easily deduce from (2), (3), (4), and partial differentiations of (1),

$$0.025\, d\vartheta_n < d\delta_n < 37.5\, d\vartheta_n \quad \ldots \ldots \tag{5}$$

$$2.5\, d(\Delta_{n-1}-\Delta_n) < d\delta_n < 75.0\, d(\Delta_{n-1}-\Delta_n) \quad \ldots \tag{6}$$

$$0.005\, dR_n < d\delta_n < 0.25\, dR_n \quad \ldots \ldots \tag{7}$$

equations to be interpreted numerically. If we consider these cases one by one, we obtain as conditions under which (5) is least favorably and most favorably applicable:

$$d\vartheta_n < 0.01; \qquad 0.375 > d\delta_n > 0.00025 \quad \ldots \tag{8}$$

$$d\vartheta_n > 0.001; \qquad 0.037 > d\delta_n > 0.000025 \ldots \tag{9}$$

respectively. Again, for the conditions under which (6) is least favorably and most favorably applicable,

$$d(\Delta_{n-1}-\Delta_n) < 0.0010; \qquad 0.075 > d\delta_n > 0.0025 \quad . \tag{10}$$

$$d(\Delta_{n-1}-\Delta_n) > 0.0001; \qquad 0.0075 > d\delta_n > 0.00025 \quad . \tag{11}$$

respectively. For (7), similarly,

$$dR < 0.01; \qquad 0.0025 > d\delta_n > 0.00005 \quad . \; . \tag{12}$$

$$dR > 0.001; \qquad 0.00025 > d\delta_n > 0.000005 \quad . \; . \tag{13}$$

respectively. An inspection of the inequalities (8) to (13) leads to the result that serious distortion from errors in the measurement of R need not be apprehended, but that the effect of errors of $\Delta_{n-1}-\Delta_n$, and to a much greater degree of ϑ, may, in unfavorable cases, influence δ_n to an alarming extent. It is, therefore, desirable to discuss in detail the probable mean errors $d\vartheta$, $d(\Delta_{n-1}-\Delta_n)$, dR, and to weigh as nicely as possible their influence on δ. In order to do this, in a measure at least, we made duplicate direct determinations of Δ after each removal of shell; and, similarly again, duplicate measurements of ϑ and R. The values for Δ, ϑ, and R, as resulting both from direct measurement and from indirect gravimetric measurement, are fully given in Tables 2, 3, 4, and 5. Table 9, however, contains a perspicuous comparison of the special differences between observed and calculated, here in question.

TABLE 9.—*Exhibit of errors of R and of ϑ.*

No. 1.			No. 2.			No. 3.		
Shell.	*dR*	*dϑ*	Shell.	*dR*	*dϑ*	Shell.	*dR*	*dϑ*
1	−0.0003	−0.0022	1	−0.0017	−0.0033	1	−0.0064	+0.0005
2	+ 016	− 014	2	+ 009	− 10	2	− 06	− 19
3	+ 031	− 017	3	+ 017	− 14	3	+ 09	− 11
4	+ 052	− 022	4	+ 037	− 28	4	+ 57	− 55
5	+ 026	− 052	5	+ 061	− 22	5	+ 33	− 66
7	+ 000	− 096	6	+ 063	+ 19	7	+ 73	− 14
8	+ 091	+ 115	7	+ 058	− 07	8	+ 66	+ 29
9	+ 064	− 062	8	+ 100	+ 20	9	+ 57	− 10
10	+ 087	+ 017	9	+ 105	− 31	10	+ 76	− 34
11	+ 074	+ 009				11	+ 72	+ 47
12	+ 120	− 101				12	+ 42	+ 10
13	+ 124	+ 092						
14	+ 089	− 020						
15	+ 091	+ 014						
16	+ 104	− 041						
17	+ 108	+ 034						
18	+ 101	− 020						
19	+ 107	+ 008						
20	+ 077	+ 050						
Numerical mean	0.0072	0.0042	Numerical mean	0.0052	0.0020	Numerical mean	0.0050	0.0027

No. 4.			No. 6.		
Shell.	*dR*	*dϑ*	Shell.	*dR*	*dϑ*
1	+0.0025	−0.0012	1	+0.0171	−0.0014
2	+ 029	+ 07	2	+ 066	+ 24
3	+ 035	− 17	3	+ 060	− 14
4	+ 079	− 73	4	+ 081	− 27
5	+ 104	+ 25	5	+ 060	+ 68
6	+ 088	+ 08	6	+ 056	− 59
7	+ 086	− 05	7	+ 096	− 23
8	+ 060	+ 61	8	+ 106	− 05
9	+ 041	− 22	9	+ 083	+ 42
Numerical mean	0.0061	0.0026	Numerical mean	0.0086	0.0031

In constructing Table 9 it was thought expedient to facilitate computation by assuming $l = 6^{cm}$. The uniform error thus introduced (except in case of No. 6, about which later) will not exceed a few tenths per cent. of excess. The unbroken character of dR is therefore attributable to other causes, principally to the fact that in view of the corroded or pitted surface of the cylinder after solution—in other words, in view of warty irregularities, which even the diamond does not satisfactorily remove—the measured value of R must be too large. To an important bearing of this result we have already alluded above (p. 31). In ϑ this uniform error is largely eliminated, because ϑ is essentially a difference.

If we take the numerical mean of the values of *dR* and $d\vartheta$ for Nos. 1 to 6, respectively, the results must yield us as safe an estimate for the mean errors of *R* and ϑ as is conveniently obtainable, even though this method be not punctiliously rigid. Table 10 shows the value of $d\delta$, corresponding to the numerical mean values under consideration (Table 9) for each of the cylinders Nos. 1 to 6, and for mean value of R, ϑ, Δ. The table is readily intelligible, since $d\delta$ is the influence of the error placed on the same horizontal row.

TABLE 10.—*Calculated (mean numerical) errors of δ.*

[$R = 1.0$; $\vartheta = 0.05$; $\Delta_n - {}_1\Delta_n = 0.0025$.]

No.	dR	$d\vartheta$	$d(\Delta_n - {}_1\Delta_n)$	$d\delta$
1		0.0042		0.0020
			0.0005	0.0050
	0.0072			0.0002
2		0.0020		0.0010
			0.0005	0.0050
	0.0052			0.0001
3		0.0027		0.0013
			0.0005	0.0050
	0.0050			0.0001
4		0.0026		0.0013
			0.0005	0.0050
	0.0061			0.0003
6		0.0031		0.0016
			0.0005	0.0050
	0.0066			0.0002

The distortion due to errors of observation enters very fully into the third decimal and may affect the second. Its mean value will not be greater than a few tenths per cent. This is by no means sufficient to invalidate the observed harmonic character of Fig. 8. It is indeed only just sufficient to permit us to replace the jagged outline of the diagram by well-rounded contours.

These data are so important as to urge further search for corroborative evidence. Fortunately, results for this end are in hand. In Tables 3 and 5 we derive δ in two ways: first, as depending on mass and density alone; secondly, as depending on dimensions and density alone. The two methods of computation both contain Δ, and are therefore not wholly distinct; but they differ from each other by one essential variation at least; and although it is again not rigidly precise, it is sufficiently in keeping with the present purpose to regard the difference between the respective values of δ as a fair estimate for the error of this quantity. For the sake of facilitating expression or of deriving a single final result, we will go one step further and regard the differences between observed and calculated δ, in Tables 3 and 5, as errors of δ considered for the time being as a constant quantity. With this assumption we reach a concise expression for the mean error of one observation. In consequence of the transcendental character of the dependence of δ on R, we know of no better method for making this evaluation. The individual and the mean errors thus derived are summarized in Tables 11 and 12.

TABLE 11.—*Exhibit of errors of δ, first series.*

No.	Shell.	Error.	No.	Shell.	Error.	No.	Shell.	Error.
1............	1	+0.008	1............	11	±0.000	3............	1	−0.010
	2	− 17		12	− 07		2	+ 08
	3	+ 03		13	± 00		3	± 00
	4	+ 01		14	+ 04		4	− 05
	5	....		15	+ 01		6	− 03
	6	− 07		16	− 03		7	− 01
	7	− 07		17	+ 01		8	+ 02
	8	+ 02		18	+ 00		9	− 08
	9	− 11		19	− 01		10	− 08
	10	+ 02		20	+ 01		11	± 00
							12	− 01
			Mean error..	......	±0.0058	Mean error..	......	±0.0041

TABLE 12.—*Exhibit of errors of δ, second series.*

No.	Shell.	Error.	No.	Shell.	Error.	No.	Shell.	Error.
2............	1	+0.015	4............	1	±0.000	6............	1	+0.002
	2	− 10		2	± 00		2	− 14
	3	− 02		3	− 01		3	± 00
	4	− 03		4	− 07		4	± 00
	5	− 04		5	± 00		5	− 03
	6	+ 01		6	+ 00		6	+ 04
	7	+ 02		7	− 01		7	+ 02
	8	− 01		8	+ 01		8	± 00
	9	− 04		9	− 01		9	± 00
Mean error ..	......	±0.0069	Mean error .	......	±0.0026	Mean error .	......	±0.0054

The magnitude of errors contained in Tables 11 and 12 is in excellent accordance with the corresponding data in Table 10. The methods of discussion are quite distinct and independent. We therefore infer with some confidence that, so far as errors of the class under consideration go, the periodic nature of the dependence of the density at a given point within the cylinder on the depth of the same point below the surface cannot be annulled or brought to merge into simpler functions.

Alike in order of importance are such errors as depend on the state of the surface of the cylinders. After removal of a shell by solution the surface is rarely glossy, most usually pitted, furrowed, and rough. In this case accurate measurement of Δ is quite difficult, because it is not easy to cleanse the surface thoroughly, either of adhering sheets of invisible air bubbles or of carbon, rust, or even metallic precipitate. Δ obtained from rough surfaces is therefore presumably too small. The objections here in question are obviated if the surface be trued and polished on the lathe with a diamond master tool; but this process may introduce a new error, even if proper precaution be taken for turning under water. The rise of temperature resulting from friction, or, indeed, the merely mechanical effect of scratching, may change the superficial temper very appreciably. In other words, the thermal effect of friction may be quite insignificant when distributed over the cylinder as a whole; but its effect in changing the stress under which the superficial shell is supposed to exist may nevertheless be marked. We take from the above tables a few data to corroborate these remarks. Roman indices refer to cylinders by number; Arabic subscripts, to shells.

TABLE 13.—*Density effect of friction.*

No., &c.	Rough.	Smooth.	Difference.	$d\delta$.
Δ_1^{ii}	7.7864	7.7892	+0.0028	+0.03
Δ_{12}^{iii}	7.7646	7.7666	+0.0020	+0.02
Δ_2^{ii}	7.7888	7.7900	+0.0012	+0.01
Δ_2^{iv}	7.7734	7.7753	+0.0019	+0.02
Δ_1^{vi}	7.7980	7.8015	+0.0035	+0.04
Δ_{12}^{j}	7.7890	7.7933	+0.0043	+0.04

Density is increased by turning to an amount as large as corresponds to the removal of a single shell; and the discrepancy $d\ \delta$ resulting may be even one-half per cent. of the density of shell sought. The part of this increment due to roughness of surface and the part due to superficial annealing cannot be distinguished; but it is clear that the data will only be sufficiently accurate for the present comparisons when cylinders of like surface, preferably smooth, are examined. If we inspect the equation of errors here involved,

$$2d\delta_n = R_n\,(\Delta_{n-1}-\Delta_n)\,\frac{-d\vartheta_n}{\vartheta_n^2}+\frac{R_n}{\vartheta_n}\,d\,(\Delta_{n-1}-\Delta_n)+\frac{\Delta_{n-1}-\Delta_n}{\vartheta_n}dR_n,$$

we find $d\delta_n$ alarmingly large when the shells are thin. Such data cannot be regarded as valid until they have been subjected to most careful and searching scrutiny.

Curiously enough, even if the rough cylinders be tested from time to time, density seems to increase. This may be regarded as an indication of slow shrinkage. Here are a few results, h denoting the interval in hours:

TABLE 14.—*Effects possibly due to shrinkage.*

No., &c.	h	Δ	Difference.
Δ_1^{iv}	0	7.7727	+0.0011.
	50	7.7738	
Δ_1^{vi}	0	7.8000	+0.0022
	50	7.8022	

The data are again of the same order as the differences of density obtained by removing a single shell. Here, therefore, is a source of error the effects of which cannot as yet even be estimated. The few data given merely suggest the importance of special inquiry.

A third class of errors results from the fact that it is nearly impossible to preserve perfect cylindricity throughout the course of the experiment. Solution is liable to take place at greater rates near the ends of the pieces of steel, as well as irregularly over the surface. The removal of matter in too great quantity from the ends must be particularly apprehended. This difficulty may be corrected to some extent by painting with asphaltum; but it is not thoroughly counteracted. Even the diamond polishes the surface without necessarily restoring the cylindrical figure completely. Hence unless great care be taken, the cylinders, after repeated solutions of shells, become more and more convex and barrel-shaped, and hence if the infinitesimal shells of the hard cylinder be coaxial and symmetrical with respect to its equator, the dissolved shell is not in full coincidence with a series of elementary shells of the cylinder. Moreover, the discrepancy is greater as the harmonic distribution of density is of small period or crowded. In such a case the true periodicity may wholly escape detection.

Again the density, δ, directly obtained is not the true density for the given distance, x, below the surface. This follows readily if it be called to mind that the structure of the tempered cylinder must be that of box-within-box. Hence if we consider the distribution of density along the nth elementary shell we must find, on passing from equator to either end, a general increase to a maximum simply because we approach parts near an end surface of the original cylinder. The analysis has already been given.

The final source of error is readily detected. We refer to superficial oxidation. It is obvious that the rapid descent of the loci of both Δ and δ for points near the surface is partially a secondary phenomenon, a simple physical expression for decarburation. To this we have already adverted (p. 33). We may add here that cracks are apparently accompanied by small values of Δ (p. 34).

It will hardly be necessary to refer to the actual measurements. The water in which steel is frequently immersed soon shows yellowish turbidity, due to suspension of rust. In replacing this by fresh water, we invariably weighed the bodies (steel) in both; but the differences between the respective values of density were negligible in all cases.

The results of this discussion may be tersely summarized thus: A first approximation reveals structure ($\delta = f(x)$), as a simple function of depth ($x = \rho_0 - \rho$) below surface, nearly independent of radius; more accurate approximation suggests an exceedingly complicated, probably harmonic function of depth. Final decision as to whether the harmonic relations in hand are true expressions for the variations of structure involved, or whether they simply indicate a periodic distribution of errors, can alone be given by frequent and laborious *repetitions* of experiments like those here described, with comparisons of all the loci obtained. The experiments must include many types of steel; for it is in this work that the quality of the material enters as a factor of exceptionally great importance. We come at once in contact with the power of retaining stress postulated in our earlier bulletin.

CONCLUSION.

The general results of the present paper have been so fully summarized in the preceding paragraph that further remarks here are nearly superfluous. But there are certain ulterior points at issue which have not yet been touched upon. In the first place, it is clear that the investigation of structure, which the present paper merely commences for the glass-hard state, is incomplete; that it must be supplemented by the nearly equally important series of data for the other definite states of temper between hard and soft. In Bulletin 14 we studied the phenomenon of annealing in its gross or aggregated effects; but the minute analysis of this phenomenon must, under given circumstances of exposure, necessarily discern differences of hardness at each point of the rod annealed. It must distinguish between the paths, as we may say, by which the consecutive individual shells eventually reach the state of homogeneous temper, while the rod as a whole passes from hard to soft.

An important observation is the dependence of structure on the quality or kind of steel carrying the hard strain, so that it may even be a sensitive criterion of the character of the material employed. Certainly it is difficult to avoid the inference that the lauded theory of dense shell and rare core, or hard shell and soft core, when regarded as a faithful expression for the structural results of temper, is quite incomplete. Under given conditions of quenching and for a given kind of steel, the hardness at a point is dependent upon the position of the said point below the surface, and will be harder or softer than the superficial layers in proportion as we pass through greater values of depth. Hence, so long as crucial evidence for or against viscous shrinkage (i. e., continuous variation of strain due to purely mechanical causes) is not in hand, so long as the strain at any point of a tempered-steel bar is persistent and *apparently* independent of the strain of surrounding parts, it will be safest to return to the venerable hypothesis of combined carbon, much in the form in which Karsten and his stalwart associates left it.[1]

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[1] We have since examined the question of structure from a variety of different standpoints. It is difficult to give satisfactory excerpts here; and the reader is therefore referred to the American Journal of this year and to forthcoming Bulletins of the Survey.—August, 1886.

B.—THE COLOR EFFECT PRODUCED BY SLOW OXIDATION OF IRON-CARBURETS.

Under this head we desire to continue the investigation on certain color phenomena peculiar to iron-carburets commenced in an earlier bulletin.[1]

Let there be given an oxide film bounded by two parallel planes, indefinite in extent, the anterior plane being continually in contact with air, the posterior plane continually in molecular contact with iron. Let the degree of oxidation at all points of any parallel plane between them be identical. If O be the oxidation in an interface at a distance x below the anterior surface, then we regard $-dO \mid dx$ as an important factor of the force in virtue of which oxygen is urged normally through the interface, in an inward direction. And, furthermore, since during the whole growth of the film the inner and outer coats remain in contact with iron and air, respectively, we must infer that $\int_0^x dO$, the difference between the degrees of oxidation of the two extreme surfaces, is constant. Hence the mean value of $dO \mid dx$ must decrease in proportion as the coat increases in thickness, and hence oxidation ceases completely after a certain finite thickness of film has been formed. Experiment shows that at each temperature the depth of film below which oxygen cannot penetrate is a quantity of definite value, increasing as temperature increases. We find moreover that oxidation advances as far as the said maximum depth gradually at a slowly decreasing rate through infinite time.

In the case of ordinary diffusion $-dO \mid dx$ would be a continuous function of x. In the present instance, however, $-dO \mid dx$ is not necessarily continuous. Regarding the character of $-dO \mid dx$ no further remark can here be made than that it must decrease continually from the anterior to the posterior face of a film. It is known that the oxide which forms on iron during heating is not of definite chemical composition. According to Roscoe and Schorlemmer[2] the inner layers are not magnetic and approximately $6\,FeO\,Fe_2O_3$. The outer layers contain more ferric oxide and are magnetic. This result for thick layers does not, however, bear any immediate relation to the composition of extremely thin films, for after the coat has increased to a certain thickness it cracks, and the phenomena are then repeated in promiscuous and irregular succession. The considerations suggested lead directly to the grained structure of matter, and we have remarked elsewhere that the oxygen molecule does not penetrate deeper than a few thousand times its own dimensions. Nevertheless the convenience of a function like $-dO \mid dx$, continuous throughout the great parts of its extent, at least, is obvious.

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[1] U. S. Geol. Surv. Bull. 27, p. 51, 1885.

[2] Roscoe and Schorlemmer, Chemistry, 1884, II, 2, p. 86.

Our observations are as yet by no means sufficiently advanced to enable us to express the final (time = ∞) thickness of film in its dependence on temperature. The data of the former paper, moreover, are incomplete in two respects: they contain only isolated values for the early stages of oxidation, which stages are important because they exhibit the time effect perspicuously; they furnish no results at all for the oxidation effect of low temperatures. To supply these deficiencies is the main object of this paper.

The method of experimentation here adopted is identical with that of the former paper. It was found expedient, however, to allow the flame of the burner to impinge upon a broad plate of brass; to place the shaft with its horizontal asbestus screen properly adjusted, upon the plate. This insures greater constancy of temperature throughout the area of base. Moreover, no discrepancy due to hot-air currents coming directly from the flame is to be apprehended. To obtain lower temperatures along the given length (25^{cm}) of shaft, we found it fairly expedient to use two brass plates with an interposed sheet of asbestus.[1] By this device the range of temperature, 180° to 300°, was reduced as far as 110° to 160°. Certain objectionable features are to be mentioned below.[2] If care be taken to avoid these, the apparatus will furnish ample facilities for the complete researches on temper value contemplated.

Data for high temperature.—The results contained in Tables 15 to 18 were investigated with a view to corroborating the results of an earlier paper.[3] The range of temperature here lies within 180° to 260°, and the dark bands or zones (colors of higher order) are to be observed chiefly during the initial stages of oxidation.

In Table 15 the approximate positions of the color zones are given by noting as accurately as possible the consecutive depths (in centimeters) of the upper and lower boundaries of the respective zones below the top of shaft as a datum. *h*, here, is the time in hours dated from the moment at which the experiment was started. The figures under "remarks" refer to the observed depth of the center of color of the "clear blue" band. The column "dark" contains data for all shades of the variously-tinged blacks which follow the gray.

In Table 16 we give results for the successive distributions of temperature on the shaft. "No." refers to the thermo-element of platinum and platinum-iridium (20 per cent.) used. e_{20} is the electromotive force of this couple when the hot junction is applied at a depth, *d*, and the cold junction kept constantly at 20°. From this, *t*, the temperature in degrees centigrade is calculated. The means of the results for temperature and depth are summarized in Table 17.

On the basis of Tables 15, 16, 17 we computed the results in Table 18. The depths and mean temperatures of the successive color bands are here given for each time of observation. The results for clear-blue, having been specially redetermined, are probably more accurate than the others.

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[1] See Fig. 10, p. 59.

[2] See p. 58.

[3] U. S. Geol. Surv. Bull. No. 27, p. 51.

Table 15. — *Consecutive positions of the color bands.*

Date.	h	Dark.	Steel-gray.	Light-blue.	Clear-blue.	Purple.	Brown.	Yellow.	Colorless.	Remarks.
1885.										
Sept. 15..	0	....	....	....	....	....	....	....	25–0	Flame started.
	1.5	....	....	....	....	....	....	....	25–0	Top above 100°. Bottom just visibly darkening.
	2.7	....	....	....	....	....	....	22–	–0	24.5.
	5.5	....	....	....	25–24	24–23	22–	....	–0	24.0.
	8.2	....	....	....	25–22	22–20	20–	....	–0	23.5.
	9.5	....	....	....	25–22	22–21	21–	–19	19–0	23.
Sept. 16..	24	....	25–	–22	22–19	19–18	18–	–10	10–0	20.
	33	....	25–21	21–20	20–19	19–17	17–	–8	8–0	19.5.
Sept. 17..	48	....	25–21	21–19	19–18	18–16	16–10	10–5	5–0	19.5.
	58	....	25–21	21–19	19–18	18–16	16–10	10–0	......	18. (Shaft may be considered colored throughout its length.)
Sept. 18..	72	25–24	24–21	21–19	19–17	17–15	15–9	9–0	......	18.
Sept. 19..	96	25–23	23–19	19–18	18–16	16–14	14–12	12–0	......	17. (Streaks of blue spoil the purity of color.)
	104	25–23	23–20	20–18	18–16	16–10	10–	–0	......	
Sept. 20..	120	25–23	23–19	19–18	18–15	15–13	13–	–0	......	16.5.
Sept. 21..	144	25–23	23–19	19–17	17–15	15–14	14–10	10–0	......	16.
Sept. 22..	168	25–22	22–18	18–16	16–14	14–12	12–	–0	......	15.
	175	....	....	....	....	....	....	....	......	15.

Table 16. — *Successive distributions of temperature.*

Time.	No.	d	[illegible]	t	Time.	No.	d	[illegible]	t
h				°	h				°
10........................	35	0	1360	178	58........................	35	24	2141	260
10........................	35	12	1470	191	96........................	35	0	1243	164
10........................	35	24	2053	253	96........................	35	12	1439	187
34........................	35	0	1284	170	96........................	35	24	2009	247
34........................	35	12	1533	197	145........................	35	0	1277	170
34........................	35	24	1975	245	145........................	35	12	1506	194
58........................	35	0	1243	160	145........................	35	24	2118	258
58........................	35	12	1455	190					

TABLE 17.—*Distribution of temperature—mean values.*

d=	0	5	10	15	20	23
t=	169	175	186	202	227	247

TABLE 18.—*Average temperatures of the successive color bands.*

Date.	h	Gray.		Light-blue.		Clear-blue.		Purple.		Brown.		Yellow.		Colorless.	
		d	t	d	t	d	t	d	t	d	t	d	t	d	t
Sept. 15, 1885	0														
	2.7					24	280								
	5.5					24	270	23	260						
	8.2					23	265	20	232						
	9.5					23	260	21	240			20	232	19	225
	24	24	270			20	232	19	225					10	185
Sept. 16, 1885	33	23	260	21	240	19	229	18	219					8	178
Sept. 17, 1885	48	28	260	20	232	18	225	17	214	14	200	7	177	5	172
	58	23	260	20	232	18	220	17	214	14	200	5	172	0	168
Sept. 18, 1885	72	22	250	20	232	17	216	17	214	12	191	5	172		
Sept. 19, 1885	96	21	240	19	225	17	214	15	204	13	195	6	173		
	104	21	240	19	225	17	214	13	195						
Sept. 20, 1885	120	21	240	18	219	16	211	14	200						
Sept. 21, 1885	144	21	240	18	219	16	209	14	200	12	191	5	172		
Sept. 22, 1885	168	20	230	17	214	15	204	13	195						
	175					15	202								

In the accompanying figure (Fig. 9) the temperature at the center of figure of the clear blue band is graphically represented in its variation with time. The diagram contains both present and early observations, the former being distinguished by small circles, the latter by crosses. Table 18, moreover, would enable us to construct similar loci

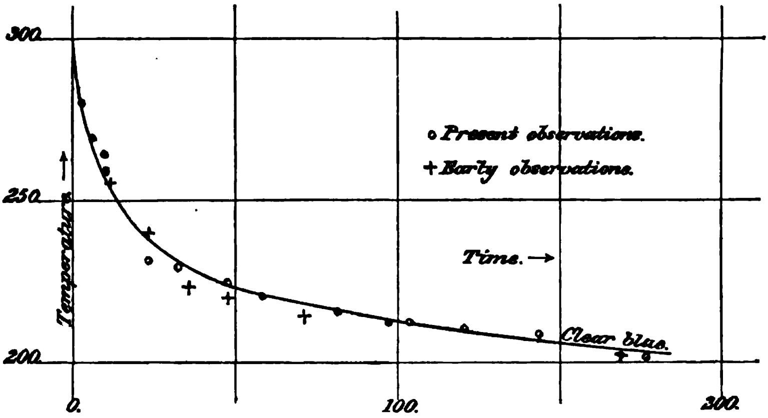

FIG. 9. Temperature of the mean "clear blue" film, regarded as a function of time.

for the zones gray, light blue, purple, brown, yellow, colorless. But the data for these colors are neither so complete nor so accurate; they show like contours with the clear-blue curve, and differ from it chiefly in position. They are omitted to avoid confusion in the diagram.

The discrepancy between the present and former loci clear blue is nowhere larger than 10°. In consideration of the large sources of error and uncertainty involved in color measurements, this accordance is obviously satisfactory. We obtain a thorough corroboration of the earlier result, viz, that the conditions under which any given color is reached in normal atmospheric air depend both on the time and on the temperature of exposure in such a way that the influence of time more and more nearly vanishes in proportion as the exposure is indefinitely prolonged. Ultimately, therefore, the color datum is a function of temperature only.

When the (hot) shaft is allowed to cool after the ordinary circumstances of exposure, we find that after 6 hours of cooling it is just warm to the touch. We infer, conversely, that the thermal condition must necessarily become stationary within the first 10 hours of heating. Now, the upward movement of the color zones on the shaft is still marked after 200 hours, and hence cannot be seriously distorted by irregularities of heating at the inception of the experiment.

We may remark that when spread over large areas of planed wrought iron the oxide coloration is apparently less brilliant than when comprehended between isothermals lying very closely together. Probably streaks of color due to irregularities in the surface (unpolished) interfere with the purity of the tints. Hence the use of thinner cylindrical rods which the colors, as a whole, would encircle like a narrow girdle may be quite as good a method of experiment as the present: for temperature may be interpolated with accuracy for observations made at points of the rod on both sides of the girdle. Such rods should be of steel and well polished.

Data for low temperature.—Tables 19, 20, 21, and 22 are constructed on the same plan as Tables 15, 16, 17, and 18, and differ from them only in that the results given hold for lower ranges of temperature. The tables follow. Depths are expressed in centimeters, time in hours, temperatures in degrees centigrade.

TABLE 19.—*Consecutive positions of the color bands.*

Date.	*h*	Blue.	Purple.	Brown.	Straw-yellow.	Light-yellow.	Colorless.	Remarks.
Sept. 26, 1885	0	....	....	....	....	....	....	Experiment started.
Sept. 27, 1885	23	....	.... ..	....	....	25–22	22–0	Color scarcely perceptible.
Sept. 28, 1885	48	....	.... ..	....	....	25–21	21–0	
Sept. 30, 1885	87	....	....	....	....	25–21	21–0	Color still very faint.
Oct. 2, 1885	137	....	....	25–22	22–20	20–14	14–0	
Oct. 3, 1885	161	....	....	25–23	23–19	19–12	12–0	
Oct. 6, 1885	233	....	25–24	24–22	22–19	19–12	12–0	
Oct. 7, 1885	257	....	25–23	....	23–19	19–14	14–0	
Oct. 8, 1885	280	....	25–23	23–21	21–19	19–14	14–0	
Oct. 9, 1885	305	....	25–22	....	22–18	18–14	14–0	
Oct. 10, 1885	334	....	25–22	22–20	20–17	17–12	12–0	
Oct. 11, 1885	353	....	25–22	22–20	20–18	18–14	14–0	
Oct. 13, 1885	401	25–24	25–22	22–20	20–17	17–13	13–0	
Oct. 14, 1885	425	25–24	25–22	22–19	19–17	17–13	13–0	
Oct. 16, 1885	478	25–24	25–22	22–19	19–17	17–13	13–0	
Oct. 17, 1885	498	25–24	24–21	21–19	19–17	17–12	12–0	
Oct. 20, 1885	568	25–24	24–22	22–19	19–16	16–12	12–0	
Oct. 22, 1885	616	25–24	24–22	22–19	19–16	16–12	12–0	
Oct. 23, 1885	644	25–24	24–21	21–18	18–15	15–12	12–0	
Oct. 25, 1885	688	25–24	24–22	22–18	18–16	16–12	12–0	
Oct. 26, 1885	711	25–24	24–22	22–19	19–17	17–12	12–0	
Oct. 29, 1885	789	25–24	24–22	21–19	19–16	16–12	12–0	
Nov. 2, 1885	887	25–24	24–22	22–18	18–15	15–12	12–0	
	890	....	....	......	....	....	....	Gas out.
	890	25–23	23–21	21–19	19–17	17–14	14–0	Remaining faces of the cold shaft.[a]
	890	25–24	24–22	22–19	19–18	18–13	13–0	
	890	25–23	23–20	20–18	18–16	16–11	11–0	

[a] The thick asbestus screen surrounding the shaft covers the part between 25.0 and 24.5. This part is faintly discolored as a consequence.

TABLE 20.—*Successive distributions of temperature.*

Time.	No.	e_{20}	*d*	*t*	Time.	No.	e_{20}	*d*	*t*
h					*h*				
23	35	749	0	111	280	35	771	0	113
23	......	849	12	124	280	......	867	12	125
23	......	1142	24	154	280	......	1197	24	160
48	35	774	0	114	385	35	752	0	110
48	......	892	12	126	385	......	849	12	124
48	......	1216	24	162	385	......	1192	24	159
87	35	764	0	113	575	35	•740	0	109
87	......	887	12	126	575	......	860	12	125
87	......	1199	24	160	575	......	1174	24	156
137	35	745	0	110	715	35	698	0	105
137	......	867	12	125	715	......	843	12	121
137	......	1166	24	157	715	......	1118	24	152
185	35	791	0	115	890	35	655	0	100
185	......	889	12	126	890	......	763	12	111
185	......	1224	24	162	890	......	1056	24	146

TABLE 21.—*Distribution of temperature—mean values.*

d=	0	5	10	15	20	23
t=	110°	113°	119°	129°	143°	154°

TABLE 22.—*Average temperatures of the successive color bands.*

Date.	*h*.	Blue.		Purple.		Brown.		Straw-yellow.		Light-yellow.		Colorless.	
		d.	*t*.	*d*.	*t*.	*d*.	*t*.	*d*.	*t*.	*d*.	*t*.	*d*.	*t*.
Sept. 26, 1885	0	....	300	....	280	....	260	....	240	....	220	....	200
Sept. 27, 1885	23	....	......	....	......	....	......	....	......	....	......	22	149
Sept. 28, 1885	48	....	......	....	......	....	......	....	......	23	154	21	145
Sept. 30, 1885	87	....	......	....	......	....	......	....	......	23	154	21	145
Oct. 2, 1885	137	....	......	....	......	24	157	21	145	17	134	14	126
Oct. 3, 1885	161	....	......	....	......	24	155	21	145	16	130	12	123
Oct. 6, 1885	233	....	......	24	160	23	153	21	144	16	134	12	123
Oct. 7, 1885	257	....	......	24	157	....	......	21	145	16	134	14	126
Oct. 8, 1885	280	....	......	24	157	22	149	20	144	16	134	14	126
Oct. 9, 1885	305	....	......	24	155	....	......	20	144	16	132	14	126
Oct. 10, 1885	334	....	......	24	155	21	146	19	137	15	128	12	123
Oct. 11, 1885	353	....	......	24	155	21	146	19	140	16	132	14	126
Oct. 13, 1885	401	24	160	23	154	21	140	19	137	15	129	13	125
Oct. 14, 1885	425	24	160	23	154	20	144	18	136	15	129	13	125
Oct. 16, 1885	478	24	160	23	154	20	144	18	136	15	129	13	125
Oct. 17, 1885	498	24	160	22	151	20	143	18	136	14	127	12	123
Oct. 20, 1885	568	24	160	23	154	20	144	18	135	14	126	12	123
Oct. 22, 1885	616	24	160	23	154	20	144	17	135	14	126	12	123
Oct. 23, 1885	644	24	160	23	154	20	143	16	134	13	126	12	123
Oct. 25, 1885	688	24	160	23	154	20	143	17	134	14	126	12	123
Oct. 26, 1885	711	24	160	23	154	20	144	18	136	14	127	12	123
Oct. 29, 1885	789	24	160	23	154	20	143	17	134	14	126	12	123
Nov. 2, 1885	887	24	160	23	154	20	143	17	134	14	126	12	123

An inspection of the loci of the data given in Tables 19 to 22, where for stated colors mean temperature is expressed in function of time, shows this: In most cases only such parts of the respective curves as are almost indistinguishable from the asymptotes have been observed. In the earlier Bulletin,[1] and in the first parts of the present paper, evidence was adduced to prove that the influence of temperature to produce color bands, the order of which increases continuously with time, is particularly marked during the first 100 hours of exposure and is very nearly complete within 200 hours. In Tables 19 to 22 the blue purple bands did not rise observably above the horizontal screen until more than 200 hours had elapsed after the beginning of the experiment. These bands, moreover, extend upward not more than 2^{cm} above the base of the shaft. At points so near the bottom the fluctuations in the intensity of flame are not yet either obliterated or rounded. It is therefore possible that during the night hours, or at other times when measurements were not made, these parts may have temporarily shown temperatures appreciably above the mean values of the set of ten series of measurements in hand. Hence the dark bands may owe their origin to temperatures above the exceptionally low values given in the tables. Finally, at points near the base and (hot) screen, oxidation is probably accelerated because the oxidizing air impinges at a temperature necessarily higher than is that of the air near the upper parts of the shaft. This, therefore, is a second cause for the unusually low temperatures at which dark zones have here been obtained.

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[1] U. S. Geol. Surv. Bull. 27, p. 51.

Remarks of a similar kind apply in a measure to the dark yellows—brown and straw-yellow. The colors did not emerge above the screen, and hence observation was not feasible until 100 hours after the beginning of the experiment. The lines obtained are practically asymptotes; the temperatures are too low.

The present set of measurements is therefore interesting chiefly because of the values obtained for the oxidation of low temperatures. The light yellow and colorless parts of the shaft are so high above the base that the objections which hold for dark bands are no longer applicable. Moreover, the temperature discrepancy in question can only give additional weight to the inferences presently to be drawn. It appears, therefore, that under ordinary atmospheric conditions temperatures falling below 125° will not perceptibly oxidize iron (color effect), however long their action may be continued. It appears, furthermore, that the effect of temperatures near this limit is such that the final tint or color of highest order is in any given case reached in a comparatively short time; or that it is reached at a stage of progress certainly quite as early as that observed for dark bands. Here, then, we observe a difference in the temper effect and the color effect of temperature; since in the former case (of annealing) the influence of time is particularly marked for lower temperatures ($<100°$); whereas for higher temperatures ($>200°$) it is nearly negligible. The result for color phenomena is almost the converse of this, since the time effect here is rather more marked, and prolonged through greater intervals, for dark bands than for very light bands. Finally we may observe, in a general way, that the annealing effect of the action of temperature on hard steel is as nearly complete in a few hours as is the color effect in a few hundred hours—a difference which will probably be crucial.

The color phenomena in question may be made to appear in another aspect. We may discuss the rate at which for a given temperature the thickness of coat varies when exposure is prolonged indefinitely. A method of using monochromatic light of wave length λ and of determining the thickness d of film from $d=n\frac{\lambda}{4}$, where n is the order of the band, is here inapplicable. The bands are too broad and diffused and the temperature variation within the first band is of considerable importance.

Nevertheless, the colors appearing in white light are available for obtaining the datum sought, and the above results may thus be interpreted. It is, however, best to omit this comparison here. For the purpose in question, it is desirable to obtain the colors in the state of extreme purity in which they appear on a *polished* steel cylinder. Mr. William Grunow, of West Point, has been at great pains to furnish us with a steel shaft of this kind, 25^{cm} long and 6.5^{cm} in diameter. The shaft in position, M M M M, is shown in the accompanying diagram, Fig. 10, in which *a a* are plates of metal between which a sheet of asbestus may be interposed. A screen, S S, fully 35^{cm} in diameter, protects the shaft from direct flame currents. The essential feature of this arrangement is the vertical hole *c c*, 0.5^{cm} in diameter, and extending to within a few millimeters of the base. Into this we purpose to introduce, momentarily, a properly insulated thermo-couple to determine the thermal distribution throughout the length of the shaft; it is generally to be used for the reception of glass-hard steel wire. Between any given and any known isothermals, therefore, we have on the outside of the polished cylindrical surface certain clear color effects. Between the same isothermals we have also a definite annealing effect, determinable by examining the parts of the steel wires there exposed. From a comparison of these data the temper value of the oxide colors is deducible in full generality. We may add that under certain circum-

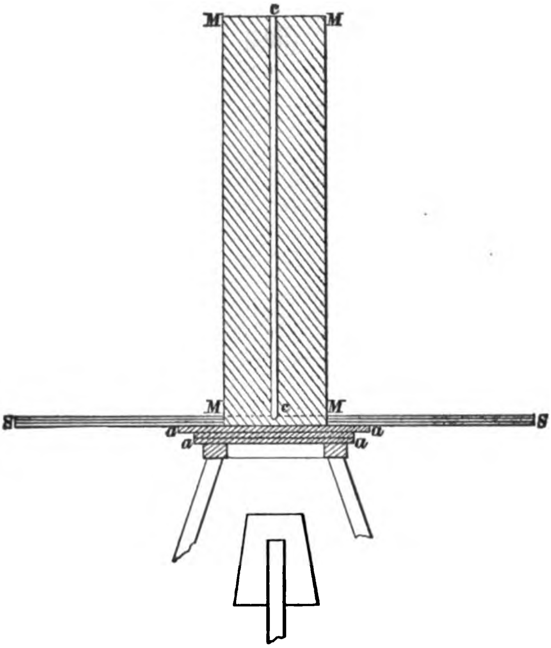

FIG. 10. Grunow's shaft, in position.

stances it may be desirable to invert the cylinder; to introduce the steel wires and the elements alternately from below, and to heat the shaft in some appropriate way at the top. Indeed it appears to us that rods bored on the gun-barrel principle would offer very satisfactory objects for accurate measurements of heat conductivity; for the advantages of measuring the (constant) temperature at any point in the interior of a narrow vertical cylindrical canal, closed above, over measuring the corresponding temperature at the mantle of the rod, are obvious at once.

WASHINGTON–PRAGUE, *January*, 1886.

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NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume V.

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J. W. POWELL, DIRECTOR

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SUBSIDENCE
OF
FINE SOLID PARTICLES IN LIQUIDS

BY

CARL BARUS

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF CHEMISTRY AND PHYSICS,
Washington, D. C., January 18, 1886.

SIR: I have the honor to transmit, through Prof. F. W. Clarke, Chief Chemist, the accompanying paper on the subsidence of fine particles of insoluble solid in liquids for publication as a bulletin of the Survey.

Very respectfully,

CARL BARUS.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

SUBSIDENCE OF FINE SOLID PARTICLES IN LIQUIDS.

By CARL BARUS.

CHAPTER I.

GENERAL RELATIONS OF THE PHENOMENON OF SUBSIDENCE.

INTRODUCTORY.

The remarks in this paper were suggested by Prof. W. H. Brewer's memoir on sedimentation, to a condensed account of which I had the honor of listening at the New Haven meeting of the National Academy of Sciences, November, 1883.

It is my endeavor in Chapter I to analyze the phenomenon of subsidence into parts such that the conditions under which subsidence is to be explained from a chemical or from a physical point of view may be better discernible. As an attempt is made to cover as much ground as possible, the chapter is largely qualitative in character. With these data in hand I then begin the quantitative study of but one of the more important features of subsidence. The results of this work are given in Chapter II.

I may add that the present interruption of the work, at a very interesting stage of progress, is unavoidable. Whether or not the work will be resumed at an early day, I cannot tell; I have therefore carried it as far as I can without special apparatus for very constant temperatures. Without these facilities the nice discrimination between the arbitrary thermal effects (convection, viscosity) and what I believe is an important subsidence phenomenon (stratification), is not satisfactorily feasible.

If thoroughly triturated insoluble material (clay, rock) is shaken up with distilled water and then allowed to subside, the solid particles will descend gradually and at a rate depending on their respective degrees of comminution. Particles may readily be obtained so fine that their rate of subsidence is practically infinite. These, therefore, remain suspended in the water indefinitely, giving rise to permanent opalescent turbidity.[1] In endeavoring to account for this occurrence some of the gentlemen present at the meeting were inclined to refer it to a case of hydration. The ultimate particles are supposed to combine with water, forming colloidal hydrates in a way analogous to the known behavior of silica. I accepted this hypothesis in the above simple form with great hesitation. It is, I believe, without *direct* proof, and probably does not admit of it; and my original purpose in writing this paper was so to exhibit the phenomena that I could dispense with the auxiliary chemical assumption. When viewed in the light given by the details of physical experiment the hypothesis is also incomplete. It does not even account for the observed suspension, inasmuch as it gives no sufficient reason why hydrated particles should be more readily suspended than particles which are not so affected. At least, if we regard the rate of descent as a function of the dimensions of the subsiding particles, then the chemical view assumes that the very fine particles descend under conditions essentially different from the coarser ones—a complication for which I saw no real necessity. Dust is suspended permanently in air under circumstances where hydration is impossible. Furthermore, what is the effect of hydration upon the particles? Are they disintegrated into molecules?—then the liquid should not be turbid, but clear. Or is the effect merely superficial?—then fine and coarse particles present *surfaces of like nature* to the liquid in which they are suspended: their rate of descent, varying solely with the frictional resistance in their progress through the given liquid, must be expressible by a general and purely physical law in terms of their dimensions, figure, and density. From this law, moreover, must the effects to be anticipated be deducible when the particles are so small as to be comparable in size with the molecules of the liquid.

The application of this good working hypothesis showed, contrary to my expectations, that any theory which is based exclusively on physical causes is untenable.[2] If, in the case of gases, internal friction is a kinetic phenomenon, it is certainly no longer wholly so in the case of liquids. It appears from my results, I think, that the chemical relation of the suspended solid to the liquid very materially influences the frictional resistance encountered by the particles. For given pairs of solid and liquid, however, this effect remains constant; it is thus seen that the auxiliary supposition of a chemical influence is neither essential to the physical explanations to be attempted nor incompatible with them, and that the whole discussion may be expediently subdivided into physical and chemical parts.

---

[1] Professor Brewer found that even after five or six years this turbidity still continued. In studying these phenomena quantitatively particles of some convenient finite size must of course be dealt with. I shall use the term "descend" throughout. A particle which is "stationary" has an infinite rate of descent.

[2] Hydration or similar action might have been assumed as an immediate datum of the theory of mass-action.

When a liquid is forced through capillary tubes the outer layers adhere to the walls of the tubes, and the friction encountered is that between the layers of the liquid; and hence this friction, or, in other words, the viscosity of the respective liquids, is, cæteris paribus, proportional to the times of efflux of given fixed quantities. The same fact is observed in various ways—indeed, wherever liquids flow over solids. But the rates of descent of given very fine solid particles suspended in liquids bear no obvious relation to the respective viscosities of the liquids. At least, so far as the evidence from my experiments goes, where unusually large ranges of viscosity are excluded, this is the unavoidable result. In the earlier portions of the present paper it will for this reason often be *temporarily* convenient to speak as though in the case of subsidence the solid particle itself actually falls through the liquid; that it is not surrounded by an adhering layer of liquid in a way to necessitate a descent of solid particle and liquid envelope, as a system.[1]

It may still be added that the comminuted material is not to be introduced into the liquid in such a quantity that the particles in their descent would interfere with one another. All remarks, therefore, apply as it were to dilute mixtures.

Mr. Durham[2] was the first to make experiments on the phenomenon of suspension, and our knowledge of the effect of precipitants is largely due to him. Similar experiments were made at about the same time by Hunt.[3] To Professor Brewer's paper reference has been made. I am aware that Prof. C. R. Stuntz, of Cincinnati, has made similar experiments. But the general trend of the researches of these gentlemen is not such, I believe, as to be intersected by my work. My thanks are due to Prof. M. C. White, of New Haven, by whose large experience in microscopic research I have profited.

GENERAL INFERENCES.

Analogies.—The problem immediately suggests an inquiry into the general cause for the suspension of finely comminuted material. If a solid particle is so small that the force of the efficient gravity-component acting upon it is less than the frictional resistance which would be encountered during a downward motion through the molecules of the liquid, then the particle must remain fixed in position relative to the walls of the liquid which inclose it. The degree of comminution necessary for apparent suspension is readily obtainable, even in the case of gases. Maxwell,[1] using Stokes's formulæ and his own value for the viscosity of air, shows that a drop of water whose diameter (0.0025 cm.) is about one-half that of a human hair would descend in air one thousand times rarer than itself at a rate of only 2 cm. per second. The rate of descent of particles of like figure and density varies as the square of their linear dimensions. It follows that if we diminish the diameter of the particle a hundred fold we diminish its rate of descent ten thousand fold; hence a drop the dimensions of which lie near the limit of microscopic vision[2] (say, 0.000025 cm.) is practically stationary, its rate being 0.0002 cm. per second.

---

[1] In the cases both of gases and of liquids the friction (external) of the fluid on the solid is enormously large in comparison with the friction (internal) of the fluid on itself. The external friction of gases is measurable only when the gas is in a state of great tenuity. (Kundt and Warburg, Pogg. Ann., CLV, pp. 337 and 525, 1875.) Successful experiments on the external friction of liquids were made by Helmholtz and Piotrowski. (Wiener Sitzungsber., XL, p. 607, 1860.)

[2] Durham, Chem. News, XXX, p. 57, 1874; ibid., XXXVII, pp. 47, 48, 1878.

[3] Hunt, Proc. Bost. Soc. Nat. Hist., p. 302, Feb., 1874.

Returning from this digression to water, which is comparatively so much more viscous than air, we find the conditions for suspension proportionately favorable. We reasonably infer that the dimensions of the particle which will just descend are correspondingly increased. We conclude that the suspension of solid dust in a fluid is to be referred to the occurrence of molecular friction.

The physical variables.—Problems connected with the motion of solids in an incompressible fluid frequently present formidable difficulties or lead to involved results. But for the comparatively simple case in hand—i. e., the conditions of uniform motion of a small spherule of radius R falling through a liquid by its own weight—the final result is fortunately simple. Let P be the resistance encountered by a spherule moving through a liquid whose frictional constant is k at a given rate x. Then[3]

$$P=6\pi kRx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

on the other hand, the effective part of the force of gravity is expressible by

$$P'=\frac{4\pi}{3}R^3(\rho-\rho')g \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where P' is the actuating force, g the acceleration of gravity, and ρ and ρ' the densities of the solid particle and the liquid, respectively. Under conditions of uniform motion $P = P'$, and hence

$$x=\frac{2}{9k}R^2(\rho-\rho')g=AR^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where A is a constant.

If there be no chemical relation between the solid and the liquid, then the constants in equation (3), or values proportional to them, are all experimentally determinable. The equation yields the mean value of R. If, however, the liquid acts chemically on the suspended solid (as would be the case, for instance, in hydration), then equation (3) is but a single relation for three unknown quantities, k, R, ρ. We may add that the relation between R, ρ, and mass of particle, leads us no further, since we know nothing of the change of mass involved.

---

[1] Theory of Heat. (Appleton & Co., 1883, pp. 299, 300.)

[2] Theoretically, according to Helmholtz, $\frac{1}{36360}$ cm. and $\frac{1}{48480}$ cm. for the ordinary and immersion systems, respectively. The limit of visibility, as experimentally found by Harting, is $\frac{1}{33130}$ cm., and by Dippel, $\frac{1}{35000}$ cm. On the other hand, strong coloring matter may be diluted as much as 100,000,000 times (Muschenbrœck, Achard, Hoffmann) without fading beyond recognition.

[3] Kirchhoff (Math. Physik, p. 381, Leipzig, 1876) deduces this equation.

Here, I think, we strike the keynote of one of the main difficulties which these phenomena present. Our assurance that the particle is not in some way acted on by the liquid is never perfect, nor have we to guide us any clew as to the effect of "mass-action," the amount of superficial change, or the depth of penetration of water, for instance. Water shows a striking selective power in discriminating between degrees of comminution. At ordinary temperatures the particles remain granular. The impression received in the case of subsidence in ether is almost that of particles falling in vacuo; barring flotation, small and large particles seem to fall equally fast; the precipitate is flocculent. Let water and ether be mixed, so that there shall be equal bulks of etherized water below and aqueous ether above, and then let the dust be added. If now this mixture is violently shaken and thereupon allowed to subside, the ether is washed clean of particles in a few minutes, whereas the sediment remains suspended in the water for weeks or even months. Another experiment, very nearly the converse of this, may be added. If a turbid solution of shellac in alcohol be shaken with naphtha, the opaque material is washed out, gradually ascending to float in the naphtha on the shellac. Subsidence then takes place in the naphtha. Eventually the two liquids (naphtha above and the clear alcoholic solution of shellac below) are separated by a layer of compacted sediment.

Whatever the surface change may be, it necessarily becomes more and more effective in proportion as the particle decreases in size. That the radius of many particles is smaller than the depth of surface penetration is quite probable. And hence, in equation (3), ρ and R must be regarded as variable—the former very largely so; whereas k may a priori be assumed as constant.[1] When liquids are forced through capillary tubes none of these difficulties are encountered, and hence their observed friction is the true viscosity of the transpiring liquid.

STRATIFICATION.

Analogies.—If very finely comminuted material be suspended in distilled water, the subsidence usually takes place in such a way that while the very slow descent of particles is in progress the liquid presents a stratified appearance. A single surface or plane of demarkation is readily observable, or indeed a number of planes, oftentimes sharply defined. This phenomenon is quite puzzling. At first sight we call to mind that air rendered densely turbid by suspended particles of water behaves practically like a distinct liquid, possessing determinate hydrostatic properties. A heavy fog will fall through pure air and subside in the valleys. Fogs of less specific gravity than air rise as clouds. Hence it would appear that in the case of subsidence of solid particles in liquids cognizance must be taken of two kinds of motion: a gradual descent of the whole mass of particles in virtue of gravity in the first place and a rearrangement of the various parts of the liquid in a way consistent with their respective specific gravities in the second. It follows that, to allow the second process or redistribution to come fully into effect, the rate of subsidence must be sufficiently small. Now, the experiments given below (p. 27) seem to show that this is often the case. If, for instance, we so adjust the consistency of the liquids in a number of sedimentation glasses that the rate of subsidence increases from tube to tube in some regular order—a condition of things which we may easily effect in a way to be indicated in the next paragraph—we shall find that surfaces are obtainable only when the rate of subsidence falls below a certain value. After this the liquid clarifies in such a manner that surfaces of demarkation are nowhere visible, passing from opaque turbidity through translucency to clearness sooner at the top than at the bottom of the tube.

---

[1] Unfortunately mere variation of ρ and R in plausible amounts for constant k does not satisfactorily account for the observed enormous changes of rate. An attempt to reconcile this discrepancy is made in the sequel. It is difficult to retain a fixed value of k throughout. If the viscosity of water is studied with particles of graded size the large corpuscles may exhibit distinct relations to the viscosity of the liquid, such as gradually vanish when we approach the extremely fine particles.

Descriptive equation.—The serious objection to this plausible view is that it presupposes a degree of imperfect mixture of the parts of the turbid liquid which *at the outset* of the actual experiment is hardly met with.[1] Indeed I believe that the occurrence of sharply defined surfaces singly is rather to be regarded as the result of accident, for the particles with which our experiments are most usually conducted (clayey material, tripoli) have already undergone subsidence in nature. They have passed through a selective process which has thrown particles of like rates of subsidence together. These particles need not be of a size; but their figures, dimensions, densities must be such as in each case to correspond to the observed rate. I will suppose, therefore, that in a general case of triturated material the particles vary in size from a very small to a relatively large value, but that by far the greater number approach a certain mean figure and dimension.

There is a distributive equation of frequent occurrence in mathematical physics which contains a characteristic maximum. In the kinetic theory of gases it expresses Maxwell's well known law, and may then be reduced to the very elegant form

$$y = \frac{4}{\sqrt{\pi}} x^2 e^{-x^2}$$

where y is the probability of occurrence of the molecular velocity, x, expressed in terms of the most probable velocity. This law of distribution may advantageously be adopted here, granting of course that the selection made is wholly empiric. I therefore postulate

---

[1] See p. 20.

$$y = \frac{4}{\sqrt{\pi}} x^2 e^{-x^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where y is the probability of the rate of subsidence x expressed in terms of the most probable rate. Hence ydx denotes the number of particles, relative to the total number, whose velocity in terms of the unit[1] specified lies between x and $x + dx$. The maximum of equation (4) is well adapted to illustrate the consequences of subsidence, when the particles vary in size as much as in an ordinary case of trituration.

Suppose the turbid liquid characterized by the function y to be inclosed between vertical parallel plates, then the degree of opacity observed on looking through the trough in the direction of a normally impinging beam of light is due partially to absorption and partially to diffuse reflection at the surfaces of the particles. As regards their effect on the transmitted beam, these two phenomena are here not essentially dissimilar and may be described by a common equation. I assume therefore the law of absorption

$$i = i_0 e^{-O\vartheta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where i_0 is the original intensity, i the reduced intensity of transmitted light in consequence of the thickness of turbid liquid ϑ, through which the beam has passed. e^{-O} is the coefficient of absorption, with the understanding that O is to refer both to the phenomena of absorption and of reflection; or, perhaps more logically, that i be the sum of two expressions each of which has the character of (5), one however referring to absorption and the other to diffuse reflection.

The signification of this constant is very clear in the differential equation

$$di = -Oi_0 d\vartheta,$$

and the problem now reduces to a consideration of the variation of O consequent upon a change in the number and position of the suspended particles. Moreover, since O varies from zero to infinity as the liquid passes continuously from clear to opaque, the constant O may conveniently be termed the opacity of the turbid liquid.

The degree of opacity, dO, which ydx particles add to the liquid is dependent on

$$ydx\,(c' \tfrac{4}{3}\pi R^3) \text{ and } (c 4\pi R^2)\, ydx \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where R is the radius of the particle whose rate of subsidence is x, and c' and c are constants. In the expressions (6), c' and its coefficient refer solely to light absorbed, c and its coefficient to light reflected;[1] but it is a fact of observation that all the phenomena under consideration appear with equal clearness when the particles illuminated by a vertical beam of light are viewed in a horizontal direction. Hence the first of the terms within the parenthesis is made negligible in comparison with the second. It follows, in view of equations (3) and (4), that the total opacity at the inception of the experiment is

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[1] If the unit of time be 1 s. then the unit of length involved is the distance passed over, per second, by the particle whose velocity is the most probable velocity. These units give compactness to Maxwell's equation. To secure similar facility of expression rates of subsidence and not radii of particles are distributed.

$$O_0=\frac{16c\sqrt{\pi}}{A}\int_0^\infty x^3e^{-x^2}dx=\frac{8c\sqrt{\pi}}{A} \quad . \ . \ . \ . \ . \ . \ . \quad (7)$$

From the elementary equations the opacity O apparent at a depth d after a time t dated from the moment at which sedimentation commenced is deducible. In view of the simplifying condition of uniformity of motion, the particle, whose rate is $x=\frac{d}{t}$ (expressed in terms of the unit above), will just have passed through the section. Hence the residual opacity is

$$O=\frac{8c\sqrt{\pi}}{A}\int_0^{\frac{d}{t}} x^3e^{-x^2}dx \quad . \ . \ . \ . \ . \ . \ . \ . \quad (8)$$

an integrable form readily reduced to

$$O=\frac{8c\sqrt{\pi}}{A}\left[1-\left(1+\frac{d^2}{t^2}\right)e^{-\frac{d^2}{t^2}}\right] \quad . \ . \ . \ . \ . \ . \ . \quad (9)$$

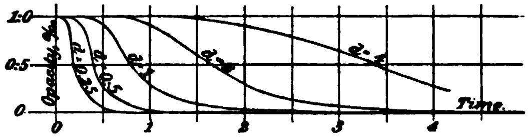

FIG. 1.—Relation of opacity to time of subsidence at different depths.

A clear view of the character of O is exhibited in Fig. 1, which contains the second factor of the second member of equation (9), time (t) as abscissa, relative opacity $\frac{O}{O_0}$ as ordinate.

The function O as given by equation (9), taken conjointly with equation (5), reproduces the march of the actual phenomenon pretty well, so long as very slow rates of descent and particles very nearly alike in size are excluded. The plane of demarkation has more fully vanished in proportion as the depth at which an observation is made is greater. An inspection of equation (9), moreover, shows that if, in place of y, we had selected a function containing a more striking and abrupt maximum[1], the function O would be characterized by steep declivity throughout greater depths or that the plane of demarkation would be more persistent. The reverse of this takes place where y is replaced by a function of flat maximum. But the important deduction is this, that if the rate of all particles is increased in like ratio the character of the phenomenon will not be changed.

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[1] The optical properties of a beam of light reflected from particles small in comparison with the wave length of light are discussed by Stokes (Phil. Trans., p. 530, 1852).

Effect of density[2] of mixture.—When the particles under experiment are practically identical in size and exceedingly small, a second phenomenon having an immediate bearing on clearness of stratification may be discerned. Indeed this new fact seems to show that for the circumstances under consideration, at least, it is not permissible to treat the particles individually; that an analysis based upon the conditions of motion of descending integrant systems of particles alone leads to the observed results. In other words, in addition to the size of the particles themselves, the dimensions of the interstitial canals separating the particles show pronounced relations to the rate of subsidence. I regard this observation sufficiently important to deserve special investigation and discussion, and shall therefore in this paper only advert to a few pertinent data.

Three test tubes, 2 cm. in diameter and 15 cm. long, were filled with distilled water to which very different quantities of tripoli had been added. The first of these, after shaking, was densely opaque; the second much less so; the third only just translucent. After the coarser material had subsided, the following results were obtained with the very fine particles. d is the distance between surface of liquid and surface of demarkation after the lapse of time h (expressed in hours); d, therefore, is the length of the clear column:

Date.	h	Very opaque. d	Opaque. d	Translucent. d
		mm.	*mm.*	*mm.*
October 9, 1885	234	12	35	50
October 13, 1885	331	20	50	77
October 15, 1885	385	29	60	90
October 16, 1885	408	33	65	96
Rate of subsidence $\frac{mm}{h}$	....	0.12	0.17	0.28
Sediment deposited	....	20	4	1

The amount of substance originally in suspension is fairly indicated by the height of the column of sediment after subsidence is complete.

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[1] The actual work usually leads to imperfect gamma-functions and involved results. This is quite unnecessary here, since the essential points are illustrated with sufficient clearness by the above. I may add that it would probably have been simpler, and at the same time more in keeping with the point of departure taken in Chapter II, to have avoided optical considerations altogether—to have simply defined turbidity as mass of sediment of a given kind per unit of volume of liquid and then to have discussed turbidity essentially in the manner pursued in the text.

[2] Measured by the number of particles per unit of volume, for instance.

The deduction from these precursory experiments of immediate interest here is this: Since the rate of descent decreases with the density of the mixture turbid liquids manifest a marked tendency toward maintaining their surfaces of demarkation clearly defined, so long at least as the particles are very nearly of a size and descend very slowly. For it is difficult to remove material out of such a surface without diluting it, but in virtue of this dilution the transported system again descends at greater rates, finally to merge into the surface out of which it was taken. Furthermore, if within a turbid liquid there exist a region of low density, these particles must subside at greater rates and eventually merge into an interior surface.

Sharp demarkation.—The presence of surfaces of separation furnishes the best available means for the investigation of rates of subsidence. When the experiment is made under satisfactory conditions the surfaces descend uniformly, and the observation may be made with some accuracy by projecting them upon a scale read off at a distance with a telescope. I have found it advantageous to place the tubes behind a black screen and illuminate the particles from above. The number and position of the surfaces is then clearly discernible, until the turbidity fades beyond recognition. With fine particles distinct surfaces appear gradually after two hundred hours—for instance, in the example discussed in the last paragraph. But they appear more rapidly on second and subsequent subsidences. We infer a time-effect due to continued contact with water.

An essential requisite for the production of sharp stratification is constancy of temperature. When temperature fluctuates convective currents arise in the liquid, transporting above its normal level and diluting some of the finer material. This in turn rearranges itself, forming a *second* (false) surface, as soon as the parts of the liquid are again at rest. Here, therefore, is an example of a fog subsiding in the liquid in the way explained in the first part of this section. But, supposing the order of occurrences reversible, this new surface would not show a depth $d=0$ for $t=0$, nor could the old surface, after this interference, be brought back to $d=0$ for $t=0$. Hence the effect of convection is virtually a change of the co-ordinates to which O, d, and t are referred. This change is irregular, and may, therefore, seriously confuse the results, since the corrective effect due to differences of density is not always sufficient, or sufficiently prolonged, to annul this discrepancy. It increases with the width of the glass; but in very narrow tubes surfaces are not discernible at all. The diameter 2.3 cm. is perhaps a good mean.

TEMPERATURE.

Chemical effect.—The subsidence of fine earthy dust suspended in distilled water is enormously more rapid at 100° than at 0°. This is easily accounted for by the hydration theory, for it is merely necessary to assume that hypothetical hydrates, which occur and are formed spontaneously at ordinary temperatures, are no longer possible at 100°. When we call to mind the augmented thermal activity of the water molecule at 100° this explanation gains much in plausibility.

Physical effect.—At this stage of the investigation it seemed to me necessary to call to mind that we are frequently operating with particles smaller than any physically measurable quantity; with particles, in other words, small even in comparison with the wave length of light and at once commensurable with molecular dimensions. It behooves us, therefore, to inquire what the anticipative conditions of subsidence will be when the dimensions of the particles decrease from some estimable mean value indefinitely. Obviously these conditions for very small particles include those for larger particles, and the special considerations to be made in the former case vanish when the dimensions increase. Hence in the sequel I shall interpret all results, with special reference to small particles, with the proviso that if the degree of comminution under experiment be insufficiently small the considerations simplify and revert to views which have already been expressed for relatively coarse particles.

In the first section I compared the effective weight of a suspended particle with the frictional resistance of the liquid. It is to be remembered, however, that the molecules of water are in a state of incessant vibration. The atoms oscillate in virtue of the internal molecular energy, and the molecule itself continually changes place and position. For very small particles; and during very small intervals of time, it is evident that this state of motion is not compatible with absolute constancy of the frictional force. We rather infer that its value varies within relatively wide limits, and the early remarks in reference to permanent opalescence have therefore tacitly assumed that the times during which gravity acts sensibly on any suspended particle are negligible in comparison with the times during which its action is without effect.

But even particles of relatively large rates of descent in water are still quite invisible microscopically (see page 35). Their linear dimensions must therefore be estimated as considerably smaller than 0.00003 cm. Hence it is safe to accept 0.000005 cm. as a fair mean expression for the diameter of the subsiding solid spherules. On the other hand the distance between the centers of two adjacent water molecules is probably not smaller than 0.00000005 cm., or about one one-hundredth of the mean diameter of the solid corpuscles.[1] It follows that the number of liquid molecules surrounding and impinging upon a suspended particle of average size varies between 10,000 and 50,000; that if, for instance, the distance between centers of two adjacent water molecules be magnified to the diameter of a pea, the subsiding solid may be typified by a bomb between a foot and a yard in diameter. The distance between the centers of two adjacent molecules is not to be confounded, however, with the diameters of the molecules themselves, and a better statement of the mean conditions involved is that of a spherical shell 0.000005 cm. in diameter and 0.00000005 cm. thick, within which, say, 30,000 molecules are free to oscillate. This number again decreases with the square of the linear dimensions of the particle. The number of molecules producing the pressure in any observable case of Boyle's law is measured in trillions. It seems to me, therefore, that where we are observing effects due to particles whose dimensions frequently fall below these mean values indefinitely, we have to take frictional forces into consideration, which, as regards all feasible measurements, are constant, but are no longer so when viewed minutely, i. e., in their variation from the beginning of any small interval of time to the next consecutive. It follows that it is possible for such a particle to descend in a liquid in virtue of the action of gravity alone, although its weight is *below* the mean or *measurable* value of the friction encountered.

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[1] O. E. Meyer (following Maxwell and Van der Waals), Kinet. Theorie der Gase, p. 226, Breslau, 1877. The value given above, which is taken directly from the kinetic theory of gases, is usually conceded to be a better estimate than the other values derived by Thomson, Maxwell, and Lorenz from capillary or electrical phenomena. Cf. Am. Journ. (2), L, pp. 38 and 258; Phil. Mag. (4), XLVI, p. 453, 1873; Pogg. Ann., CXL, p. 644, 1870.

Whatever the difference between the greatest and least values of frictional resistance during the unit of time may be (it is difficult to form a satisfactory estimate, since we know but little about the liquid molecule and its rate and manner of motion or the variation of molecular forces), we may argue fairly, I think, that the interval between the limits in question will increase with the degree of molecular activity of the liquid.[1] The particles, under conditions of intense agitation of the surrounding molecules, are more liable to be shaken through the liquid, as it were (as powders are shaken or jarred through a series of sieves, to use a common but apt comparison), than when the molecule is comparatively quiet. Hence any means which may tend decidedly to increase this molecular disturbance, even though it slightly increase viscosity (as in the case of salt solutions), may effect an increment in the rate of subsidence. These views are to be examined with some detail.

The most direct means of increasing the molecular agitation of a liquid is temperature. It is to be anticipated that the rate of subsidence of suspended particles of a given degree of comminution will be greater when the liquid is at 100°, for instance, than when it is at ordinary temperatures. I made this experiment:

Two identical glass tubes, closed at one end and drawn to a fine aperture at the other, were half filled with distilled water rendered densely turbid by dust of white bolus. Both were kept at 100° for some time, for the purpose of expelling air, then hermetically sealed with a blast lamp. The tubes measured about 0.8 cm. in diameter and 15 cm. in length. One of these was left in the room, without interference, at ordinary temperatures; the other, shaken up simultaneously with the first, was exposed to the constant temperature 100°, by suspending it in a boiling point apparatus, as shown in the annexed diagram.[1] (Fig. 2.)

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[1] The mean velocity of particles of air, at 0° C., for instance, is much over 400 meters per second. The velocity of the molecules of liquids is not known, but must be of like order.

The following results were obtained: The third and fourth columns of Table 1 give the depth *d* (in millimeters) of the plane of demarkation below the bottom of the meniscus, after a lapse of time *h* (in hours) given in the second column.

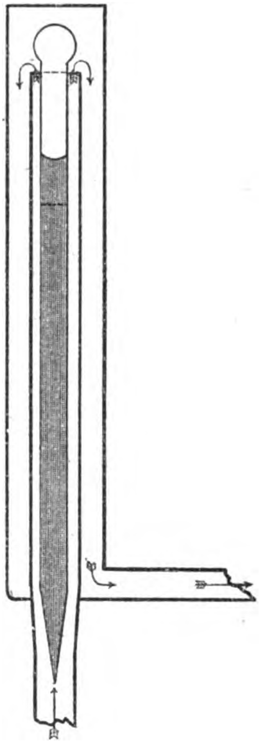

FIG. 2.—Apparatus for subsidence at 100°.

TABLE 1.—*Subsidence at* 15° *and at* 100° *compared.*

	h	*d* 15°.	*d* 100°.
First experiment	3	0	3
Rate $\left(\frac{mm}{h}\right)$	....	(0.1)	1.0
Second experiment	24	3	*clear*
Rate $\left(\frac{mm}{h}\right)$	....	0.1	(2.0)

After three hours a difference in rate is already clearly perceptible. Within 24 hours (experiment prolonged overnight) the sediment in the hot tube has completely subsided in the form of a flocculent precipitate somewhat like alumina. The cold tube is almost free from precipitate,[2] while the surface of demarkation is down only 2 to 3 mm. below the bottom of the meniscus.

The rate of subsidence proves, therefore, to be very much greater at 100° than at 15°. A result of this general character was to be anticipated, but the enormous difference of rate in the two cases is exceedingly striking. The effect of the diminished viscosity[3] at 100° would not have sunk the dust in the hot tube more than 15mm. below the meniscus.

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[1] The diagram is readily intelligible. The direction of the currents of steam is shown by the arrows. The sedimentation tube occupies a central position and is thus doubly jacketed with steam.

[2] The large amount of precipitate in the hot tube is good evidence in favor of the views on the coherence of particles, as discussed on page 37.

[3] The viscosity of water at different temperatures has been measured by Poiseuille, Rosencranz, and Slotte. (See digest of the latter, in the Ann. der Physik, XX, pp. 266, 267, 1883.) At 100° the viscosity of water is about one-sixth of its value at zero. But the corresponding rates of subsidence are in a ratio which, although qualitatively in accordance, is quantitatively out of all proportion herewith.

I will waive further discussion of this result here in consequence of quantitative comparisons which I have in view, comparisons made at different temperatures, varying between 0° and 100°. Below 100° we experiment with solid particles of a given mean size, descending or subsiding in a given liquid at determinable rates. Regarded from this standpoint the experiment is of sufficient importance to demand careful measurements.

RECIPITANTS.

Chemical effect.—Acids, salts, alkalies, indeed foreign material in general,[1] when added to distilled water permanently turbid with some finely comminuted insoluble solid in quantities not too large, increase the rate of subsidence in a marked degree, in numerous cases even many hundred fold.

The chemical theory appears very readily to suggest these phenomena. The addition of the substances enumerated interferes with or prevents the formation of the hypothetical hydrates; but the force of this explanation is apparently weakened when we pass from purely qualitative to quantitative data. By reducing some of the results below to a molecular basis, I find that a single molecule of acid or salt, in molecules of water varying in number from 10,000 to 50,000, is sufficient to produce very marked changes in the rate of subsidence. It is conceivable that this amount of dissolved material may in some instances be commensurable with the amount of suspended material, and therefore act appreciably on it. In such a case there should be a difference of rate due to a difference in the degree of turbidity of otherwise identical turbid solutions. I have failed thus far to bring satisfactory quantitative evidence to bear upon this point. I am pursuing these experiments with considerable care and therefore need merely indicate the nature of the difficulties encountered here. Instead of considering the particles individually, as has been done above (p. 14), all the particles in the unit of volume may be taken collectively. *A priori*, the only available force is gravity, and we must regard the weight of the particles in unit of volume to be the measure of the influence in virtue of which water is forced through the capillary interstices of the descending system. The analysis shows that the rate of descent of this system must decrease rapidly with the number of particles per unit of volume. Hence, the purely mechanical effect has the same sense as the hypothetical chemical effect to be investigated, and it is therefore exceedingly difficult to discriminate between the two.

Physical effect.—On the other hand, the examination into the molecular conditions of subsidence, commenced in the last section, here suggests so many analogies that further discussion is at once demanded. We have reasons for inferring that in the case of water, or perhaps any other simple liquid, there is presented to us a comparatively quiet molecule; by which I mean that dissociations and recombinations of the molecule H_2O, akin to those premised by Williamson[1] in his views on the process of etherification, and by Clausius[2] in his theory of electrolysis, are, at ordinary temperatures at least, of rare occurrence. The electrical conductivity of pure water[3] is at most one ten-billionth of that of pure mercury. It needs but very trifling admixture of acid or salt or alkali to increase this minimum value enormously. If it be remembered that as small an addition as 18 per cent. by weight of hydrochloric acid increases the conductivity of water more than a million times, it may easily be estimated how insignificant is the amount of HCl which would suffice to increase the conductivity by a fraction of itself. Even very perfect liquid insulators, like alcohol and turpentine, when added to water, produce incremental electrolytic effects. Indeed HCl, in the pure state, is an insulator of the same order as water.[4] According to Clausius, no electrolytic effect will be produced by electromotive forces of practicable magnitude, in a space where temporary dissociation[5] does not occur and partial molecules are therefore absent. Hence at ordinary temperatures the solution of one substance in another ("electrolytic system") is the essential condition of good electrolytic conductivity. It is on the basis of these facts that the assumption of a "quiet" molecule of water, in the above sense, was made. The result of mixture is molecular kinetic energy permanently gained in large amount.

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[1] The definite organic compounds (alcohols, ethers) are frequently exceptions.

Now, I believe that the dissociations which Clausius and Williamson premise present a more plausible occurrence if the separation is superinduced by an intermediate substance of known affinity for one or the other partial molecule. If a solid particle is introduced into an electrolytic system its effect upon the meandering partial molecules may be regarded as somewhat similar to electromotive force, inasmuch as in a general case different parts of the suspended solid attract partial molecules of different kinds. Furthermore, in view of the occurrence of mass-action, in view of the continually recurring dissociations and recombinations between solid and liquid, I see no avoidance of the hypothesis that the surface of the suspended particle must, in particular, be a locus of violent molecular agitation.

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[1] Williamson: Ann. der Chem. und Pharm., LXXVII, p. 37, 1857.

[2] Clausius: Mech. Wärmetheorie, 2d ed., Vol. II, p. 155–169, 1879.

[3] Measured by a number of observers, among them by F. Kohlrausch, Pogg. Ann., Erg. VIII, p. 1, 1876. Kohlrausch's last value is 30×10^{12} (Berl. Sitzb., XL, p. 3, 1884).

[4] Gore: Proc. Roy. Soc. London, p. 256, Vol. XVII, 1868–1869, and others.

[5] According to Clausius the substance (acid, salt, alkali, &c.) after solution may be regarded as an aggregate of partial molecules, such that opposite electrical properties are equally represented. Electromotive force produces a moving effect whenever the other conditions which influence a partial molecule are favorable, i. e., temporarily at a minimum. If any imaginary interface be described between the positive and the negative electrode, then more positive than negative partial molecules will pass in the direction from the positive to the negative side and more negative than positive partial molecules in the contrary direction. The result is practically this: During the action of the electromotive force a certain number of positive partial molecules pass through the interface in a positive direction and the same number of negative partial molecules in the negative direction.

Returning from this digression to the subject in hand, I infer that, just as in the above instance a marked increment of the rate of subsidence of extremely small particles suspended in water was obtained in consequence of the augmented thermal energy of the water molecules (heating to 100°), so must also an analogously increased rate result at ordinary temperatures from the intensified molecular agitation due to the solution of foreign material in water. I offer the following experiments on this point:

Experimental results.—In Table 2 the results obtained with finely comminuted white bolus, red bolus, and tripoli, respectively, each suspended in distilled water, are given. Stand-glasses, about 3 cm. in diameter and 30 cm. high, hold these mixtures. The fourth, fifth, and sixth columns of the table show the depth, *d*, of the respective surface or surfaces of demarkation below the level of the liquids at the times given in the second column. The surfaces were distinct for tripoli, less so for white bolus, washed in the case of red bolus; *d* is given in arbitrary units;[1] *h* in hours. Where two sets of figures are given, two surfaces were apparent.

TABLE 2.—*Subsidence in distilled water.*

Date.	Time of day.	*h*	*d*		
			White bolus.	Red bolus.	Tripoli.
December 24	12 p. m.	0	0	0	0
December 25	12 p. m.	24	6	3	28
December 26	2 p. m.	38	11	5	58
December 26	5 p. m.	41	12	4	61
December 27	1 a. m.	49	14	5	71
December 27	9 a. m.	57	16	5	81
December 27	8 p. m.	68	20	6	93
December 28	1 a. m.	73	20 22	6	100 104
December 28	11 a. m.	83	22	7	108 120
December 29	2 a. m.	98	24 30	7	121
December 29	11 a. m.	107	26 32	8	131
December 30	1 a. m.	121	34 29	9	140
December 30	12 m.	132	30 36	10	148
December 31	3 a. m.	147	....	....	156 165 180
December 31	12 m.	156	....	....	160 170
Rate $\left(\frac{d}{h}\right)$	....	....	0.28	0.09	1.3

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[1] About 2 mm. each.

If we regard d as a function of h we find it linear in the case of white and of red bolus and quadratically retarded in the case of tripoli, but to the latter fact I would attach no significance. It may be due to the unavoidable fluctuations of temperature.[1] So long as the descent is uniform (d proportional to h) the force acting on the particle is nil. The effect of gravity is exhausted in doing work against the frictional resistance.

In Table 3 are given the results obtained with fine tripoli suspended in distilled water to which various percentages (by weight) of common salt (NaCl) have been added. The precipitation tubes in this series of experiments were 3 cm. in diameter and 15 cm. long. Values for d are given only when planes of demarkation were observable. In other respects the table is like the preceding one, except that d is here expressed in millimeters. Where two sets of figures are given, two surfaces were apparent.

TABLE 3.—*Subsidence in salt solutions.*

Date.	Time of day.	h	d								
			0.1 per cent.	0.25 per cent.	0.5 per cent.	1.0 per cent.	2 per cent.	5 per cent.	7 per cent.	10 per cent.	15 per cent.
December 27, 1883	10 a. m.	0	0	0	0	0	0	0	0	0	0
December 27, 1883	2 p. m.	4	5	9	13	Largely down.	Sediment falls rapidly in all the tubes; rate not observable, from absence of stratification.				
December 27, 1883	6 p. m.	8	7	14	16 30	No demarkation surface.					
December 28, 1883	1 a. m.	15	11 14	29	45						
December 28, 1883	4 p. m.	30	17 26	58	87						
December 29, 1883	2 a. m.	40	42 62	85	128						
December 29, 1883	12 m	50	30 53	104	Bottom.						
December 30, 1883	1 a. m.	63	41 69	135	....						
December 30, 1883	12 m	74	47 80	Bottom.	....						
December 31, 1883	3 a. m.	89	56 95	....	....						
December 31, 1883	12 m	98	63 105	....	....						
Rate $\left(\frac{mm}{h}\right)$	....	....	1	2	3	(20)					

The experiments show that the rate of sedimentation increases rapidly with the quantity of salt in solution; that even small quantities of salt produce very marked effects; d varies linearly with h. The absence of stratification in cases of greater rates of subsidence (solutions 1 to 15 per cent.) is confirmatory of the remarks made in an earlier paragraph (p. 16) on the rearrangement of particles according to the density of different parts of the liquid and accords well with the other views there given. The remarkably accelerated increase of rate observed on passing from fractional to integral per cents. (composition) is to be noticed.

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[1] See p. 20 as to convective currents and the change of co-ordinates resulting.

Table 4 gives the results obtained with red bolus, white bolus, tripoli, talc, and bone ash, respectively, all finely comminuted and suspended in weak brine. The percentage of salt dissolved is shown at the head of each column. The solutions are held in test tubes about 1 cm. in diameter and 13 cm. long. They were mixed in a way to be indicated at the head of Table 5. In most cases surfaces of demarkation were either absent or not clearly observable; *d*, therefore, shows the depth of tints or turbidities of like density or degree below the level of the liquid measured on an arbitrary scale; *cl.* denotes clear; *tr.* translucent.

TABLE 4.—*Subsidence in salt solutions.*

Date.	Time of day.	*h*	*d*									
			Red bolus.					White bolus.				
			0.05 per cent.	0.1 per cent.	0.2 per cent.	0.4 per cent.	0.8 per cent.	0.05 per cent.	0.1 per cent.	0.2 per cent.	0.4 per cent.	0.8 per cent.
January 7, 1884	2 p.m..	0	0	0	0	0	0	0	0	0	0	0
January 7, 1884	3 p.m..	1	0	0	0	0	0	1	1	0	3	40
January 7, 1884	5 p.m..	3	0	0	0	0	0	1	2	0	6	*cl.*
January 7, 1884	6 p.m..	4	0	0	0	0	0	1	1	0	*tr.*	......
January 7, 1884	9 p.m..	7	1	1	1	2	5	1	2	3	*cl.*	.....
January 7, 1884	12 p.m..	10	1	1	1	4	30	2	2	4	......	......
January 8, 1884	3 a.m..	13	2	2	2	5	*tr.*	3	3	20	......	......
January 8, 1884	11 a.m..	21	2	2	2	4	......	3	3	*tr.*	......	......
January 8, 1884	7 p.m..	20	3	3	3	7	*cl.*	8	7	......	......	......
January 8, 1884	12 p.m..	34	4	5	6	10	......	9	10	*cl.*	......	......
January 9, 1884	10 a.m..	44	5	4	5	9	......	6	7	....	......	......
January 12, 1884	1 p.m..	119	12	13	15	25	......	21	33	......	......	......
January 13, 1884	3 p.m..	145	12	13	15	30	.....	28	38	......	......	......
Rate $\left(\frac{d}{h}\right)$	....	......	0.09	0.10	0.12	0.25	2	0.2	0.3	0.8	2	5

Date.	Time of day.	*h*	*d*														
			Tripoli.					Talc.					Bone ash.				
			0.05 per cent.	0.1 per cent.	0.2 per cent.	0.4 per cent.	0.8 per cent.	0.05 per cent.	0.1 per cent.	0.2 per cent.	0.4 per cent.	0.8 per cent.	0.05 per cent.	0.1 per cent.	0.2 per cent.	0.4 per cent.	0.8 per cent.
January 7, 1884......	2 p.m..	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January 7, 1884......	3 p.m..	1	2	2	2	1	2	2	2	3	3	4	Clarifies rapidly, at rates increasing with the quantity of salt dissolved.				
January 7, 1884......	5 p.m..	3	2	3	3	3	3	28	..	....	*cl.*	*cl.*					
January 7, 1884......	6 p.m..	4	3	6	3	4	7	....	*cl.*	*cl.*							
January 7, 1884......	9 p.m..	7	4	7	5	9	7	*cl.*	...	....	...	...					
January 7, 1884......	12 p.m..	10	7	12	7	14	*tr.*	...	....	..	....	...					
January 8, 1884......	3 a.m..	13	8	14	10	30	*l.*	....	....	....	...	..					
January 8, 1884......	11 a.m..	21	8	16	9	*tr.*	..	..	....	....	....	....					
January 8, 1884......	7 p.m..	29	12	22	24	..	...	...	....	....	....	....					
January 8, 1884......	12 p.m..	34	13	22	*tr.*	*cl.*	..	...	....	....	..	....					
January 9, 1884......	10 a.m..	44	13	25		...	..	..	....	...	....	...					
January 12, 1884.....	1 p.m..	119	*tr.*	*tr.*	*cl.*	..	....	...	....	....	....	....					
January 13, 1884 ...	3 p.m..	145	..	..			...	...	....	....	....	....					
Rate $\left(\frac{d}{h}\right)$	....	...	0.4	0.6	0.7	1.5	2	2	2	3	3	4					

The absence of stratification which frequently occurs for thin walled tubes of small diameter I refer to convection due to fluctuations of temperature. The results of this table have a smaller claim to accuracy.[1] The difference in the rates of subsidence in case of solutions of the same percentage quantity of salt is probably wholly due to differences of comminution in the various cases. An accelerated increase of rate with the strength of the brine is again generally apparent.

In Tables 5 and 6 various stages of subsidence of tripoli, in solutions of different chemical composition, are given, Table 5 showing the results obtained with 0.01 per cent. solutions, Table 6 the results for 0.05 per cent. solutions, of the anhydrous compounds HCl, H_2SO_4, $CuSO_4$, $ZnSO_4$, $MgSO_4$, KI, NaCl. In addition to the mean rates the electrical conductivities[2] of the divers solutions are added. The tables are readily intelligible. The particles subsided in tubes 3 cm. in diameter and 20 cm. long. In order to warrant the assumption that the contents of the tubes are identical, except in the respects mentioned, the following plan of mixture was pursued: One per cent. solutions of each of the substances enumerated were first prepared, after which 1 cubic centimeter and 5 cubic centimeters of each were diluted to 100 cubic centimeters with distilled water permanently turbid with tripoli. In the case of Table 4 above, equal volumes of turbid water were added to each of the tubes and the contents then diluted to the desired amount with clear distilled water. This general method gives assurance that both the number and the mean dimensions of the solid particles in each cubic centimeter of the different solutions were originally identical—a condition of essential importance.

TABLE 5.—*Subsidence in* 0.01 *per cent. solutions.*

Date.	Time of day.	*h*	*d*					
			$CuSO_4$.	KI.	NaCl.	H_2SO_4.	HCl.	H_2O.
January 6, 1884	8 p. m.	0	0	0	0	0	0	0
January 7, 1884	9 a. m.	13	......	......	......	*tr.*	*cl.*(*a*)	......
January 7, 1884	6 p. m.	22	11	5	5	......	......	......
January 7, 1884	12 p. m.	28	5 25	......	......	*cl.*	......	......
January 8, 1884	12 m ...	40	36	10	10	......	......	......
January 8, 1884	7 p. m.	47	50	......	......	......	......	......
January 9, 1884	10 a. m.	62	*tr.*	20	20	......	......	18
Rate $\left(\frac{mm}{h}\right)$	......	......	1.0	0.3	0.3	(10)	(100)	0.3
Conductivity ($\times 10^9$)	......	......	4	6	13	40	75	......

a Translucent in 1 hour and 30 minutes.

---

[1] Measurements of this kind, unless we resort to special optical apparatus, are always unsatisfactory. To the eye, however, the evidence furnished by these experiments was quite conclusive. After the expiration of a month the tubes with red bolus, for instance, were still distinctly colored, the mean tint varying in height and in degree inversely as the quantity of salt contained in the liquid.

[2] In terms of mercury.

TABLE 6.—*Subsidence in* 0.05 *per cent. solutions.*

Date.	Time of day.	*h*	*d*					
			$CuSO_4$.	KI.	NaCl.	H_2SO_4.	$MgSO_4$.	$ZnSO_4$.
January 13, 1884	5 p. m.	0	0	0	0	0	0	0
January 14, 1884	10 a. m.	17	cl.	22	20	cl.	tr.	cl.
January 21, 1884	5 p. m	192		60	60			
Rate $\left(\frac{mm}{h}\right)$				0.5	0.5			
Conductivity ($\times 10^6$)			8	12	26	80	10	8

In Table 5 surfaces of separation were apparent except in the case of HCl and H_2SO_4; in Table 6, however, they were apparent only in the case of KI and NaCl. I avoid greater length of detail in the present data, since all other desirable relations are sufficiently indicated in the earlier results.[1]

Table 7 contains the results obtained with tripoli falling through concentrated ether, absolute alcohol, water, and glycerine, respectively. Subsidence takes place in tubes like those described on page 23; *h* is in hours, *d* in millimeters.

TABLE 7.—*Subsidence in divers liquids.*

Date.	Time of day.	*h*	*d*			
			Ether.	Alcohol.	Water.	Glycerine.
January 21, 1884	10 p. m.	0.00	0	0	0	0
		0.03	9			
		0.07	16			
		0.10	21	5		
		0.13	26			
		0.17	30			
		0.20	32	10		
		0.25	36			
		0.48	43	23		
		0.75	45	34		
		1.00		44		
		1.25		53		
January 22, 1884	2 p. m.	16			2	
After 40 days						6
After 61 days						13
After 180 days						25
After 290 days						35
After 600 days						52
Rate $\left(\frac{mm}{h}\right)$			250	45	0.1	0.02

From these tables it appears that the descent is much more rapid in ether than in alcohol and enormously more so in these liquids than in water. In the case of ether the rate of subsidence decreases rapidly as time increases; but the tube is not long enough for the study of sedimentation occurring at such phenomenally large rates. Particles reach their lowest positions and pack before a normal rate is fully obvious.

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[1] The effect of HNO_3 is analogous to that of the other acids.

The supernatant liquid is clear. In case of alcohol and water it remains slightly opalescent. Surfaces of demarkation are in all cases sharp.

Values for rate of subsidence, such as are obtainable from Table 7, cannot be immediately compared. To arrive at data of this kind, the liquids (ether, alcohol, water) should be examined when in similar molecular conditions. This would, for instance, be the case when each is at its boiling point. Differences of rate, in these cases, will be much less pronounced. (See Table 1.)

An interesting feature of this experiment may be noticed here. After subsidence has taken place, in the case where about equal amounts of tripoli are originally suspended (the liquids being in tubes of like caliber), the permanent column[1] of sediment was found to be longest for ether, shortest for water, of intermediate length for alcohol: directly, therefore, as the respective rates of subsidence. But further experiments show that this is not always the rule. In the following Tables 8 and 9 the results obtained by suspending 1 gram of tripoli in various liquids are contained. l denotes the length (mm.) of a column of sediment, of a given diameter and weighing 1 gram, after complete subsidence has taken place.

TABLE 8.—*Bulk of sediment after subsidence.*

	Methyl alcohol.	Ethyl alcohol.	Ether.	Water.
After 40 days, $l =$	45	66	134	58

TABLE 9.—*Subsidence in divers liquids—bulk.*

	h	Methyl alcohol.	Ethyl alcohol.	Ether.	Water.
	0.0	0	0	....	....
	0.7	34	21	....	....
	1.1	38	38	....	....
	2.7	44	55	....	....
	12.7	48	67	....	....
	28.7	49	70	....	....
	45.7	49	72	....	....
Rate $\left(\frac{mm}{h}\right)$	....	70	40	....	....
After 21 days, $l =$	....	55	59	118	49

Methyl alcohol shows an exceptional value. In all cases the rate materially decreases as time increases and finally reaches zero asymptotically. As the particles descend they interfere with one another, and this in proportion as the quantity of sediment in the unit of volume increases. The friction of particles on themselves complicates the phenomena[2] and is without interest in the present discussion.

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[1] Bulk here varies linearly with length.

[2] "Packing" is probably due to slow descent of smaller particles between the interstices of the larger, on the hour-glass principle, until the equilibrium of position of larger masses or corpuscles is undermined.

A final exhibit of the divers rates of sedimentation encountered in the above tables, reduced to $\frac{mm}{h}$ and to $\frac{cm}{sec}$ is desirable.

TABLE 10.—*Rates of subsidence—final digest.*

1. *Subsidence in distilled water, 15° and 100°, respectively—bolus.*

15°		100°	
$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
0.1	3	1.0	30
0.1	3	2.0	60

2. *Subsidence in distilled water.*

White bole.		Red bole.		Tripoli.	
$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
0.6	20	0.2	6	2.6	80

3. *Subsidence in weak brine—tripoli.*

0.1 per cent.		0.2 per cent.		0.5 per cent.		1 per cent.	
$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
1	30	2	60	3	90	(20)	(600)

4. *Subsidence in weak brine—bole, tripoli, talc.*

	0.05 per cent.		0.1 per cent.		0.2 per cent.		0.4 per cent.		0.8 per cent.	
	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
Red bolus....	0.2	6	0.2	7	0.3	9	0.6	18	5	150
White bolus.	0.5	1.5	0.7	20	2.0	60	5	150	13	390
Tripoli	1.0	30	1.5	45	1.8	54	3.7	110	5	150
Talc	5	150	5	150	7	210	8	240	10	300

5. *Subsidence in 0.01 per cent. solutions of divers substances—tripoli.*

$CuSO_4$		KI		NaCl		H_2SO_4		HCl		H_2O	
$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
1.0	30	0.3	9	0.3	9	(10)	(300)	(100)	(3000)	0.3	9

TABLE 10.—*Rates of subsidence—final digest*—Continued.

6. *Subsidence in 0.05 per cent. solutions of divers substances—tripoli.*

$CuSO_4$		KI		NaCl		H_2SO_4		$MgSO_4$		$ZnSO_4$	
$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
......	....	0.5	1.5	0.5	1.5	......	....	......	....	......	....

7. *Subsidence in divers liquids—tripoli.*

Ether.		Alcohol.		Water.		Glycerine.	
$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
250	7500	45	1300	0.1	3	0.02	0.6

9. *Subsidence in divers liquids—tripoli.*

Methyl alcohol.		Alcohol.	
$\frac{mm}{h}$	$\frac{cm}{sec}10^6$	$\frac{mm}{h}$	$\frac{cm}{sec}10^6$
70	2000	40	1200

Facilities for obtaining absolutely constant temperatures would have much improved these crude results; but they are the best available under the circumstances. I may add that the sedimentation effect of the addition of ether and of alcohol to distilled water seems to be a decided retardation of rate,[1] and that the rate is not independent of the amount of sediment in suspension but decreases with the turbidity of the mixture. Hence even in the above experiments different rates occur in different series of experiments for this reason alone; but to these results I attach crucial importance, and shall therefore treat them specially in another paper.

DISCUSSION.

Mechanical relations.—In the equation by which I endeavored to describe the appearance of the tube at different times (p. 18), it was convenient to express depth, d, in terms of the distance traveled per second by a particle whose rate, δ, is the most probable rate. If D be the actual depth in centimeters, then $d = \frac{D}{\delta}$; and hence equation (9) takes the form

$$O = \frac{8c\sqrt{\pi}}{A}\left\{1 - \left(1 + \frac{D^2}{(\delta t)^2}\right)e^{-\frac{D^2}{(\delta t)^2}}\right\}$$

Inasmuch as δ and t enter this equation symmetrically it is evident at once that if the rate of all particles be increased n-fold the column of turbid liquid will present a given appearance or stage of subsidence in $\frac{1}{n}$ of the original time; the character of the phenomenon is not essentially changed. If, however, the increase of velocities is produced by solution of precipitants, we find experimentally that the column which presents surfaces of demarkation for the class of very weak solutions clarifies without exhibiting this characteristic feature during any stage of subsidence for the class of stronger solutions, and, furthermore, that the transition from stratified subsidence to unstratified subsidence is apparently abrupt. I infer that in the case of subsidence superinduced by precipitants the equation for the original distribution of rates, $y=f(x)$, is radically changed, and this in proportion as the amount of precipitant dissolved is greater. Furthermore, that this change is equivalent to a flattening of the maximum in the direction of greater rates; or that the difference of rate between consecutive particles is largely incremented, although not in uniform measure for all the particles. Again, surfaces of demarkation remain distinct until the (long) column as a whole fades beyond recognition. This is the essential difference between subsidence of fine particles in water, as actually observed, and simple viscous subsidence as described by equation (9), for instance.

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[1] It is well to desiccate the particles intended for subsidence in ether.

If we accept Slotte's[1] value for the viscosity of water at 20°, $k=0.0101$ (g cm^{-1} sec^{-1}), Poiseuille's[2] value for the viscosity of ether, 0.3 k, and Graham's[3] values for the viscosity of methyl alcohol and of ethyl alcohol, 0.63 k and 1.20 k, respectively; if, furthermore, we assume as the density of the subsiding substance (quartz, clay) the value $\rho=2.5$ whence $\rho'-\rho=1.5$ in round numbers; if, finally, $g=980$ (cm. sec^{-2}), then Table 10 (7 and 9) supplies the remaining data a (cm. sec^{-1}) for estimating the mean linear dimensions of the subsiding particles. We obtain

	Centimeters.
Water	$R=0.00001$
Ethyl alcohol	$R=0.00019$
Methyl alcohol	$R=0.00020$
Ether	$R=0.00024$

These results point out in a striking way the essential difference between subsidence in distilled water and subsidence in liquids (alcohols, ethers) whose affinities for silica and silicates are demonstrably feeble. The value of R is smallest in the case of water; certainly too large in the case of the remaining liquids. The dimensions found are therefore just in the inverse order of the values, which hydration would compel us to infer. The discrepancy is due in part to the value of density entering into the arguments; but the large error is more simply explained by the fact that in the two classes of experiment, even though made upon the same material, we have *different particles* under observation. I have adverted to the coagulated appearance of the sediment when submerged in ether or in alcohol. The particles cohere closely, and the coarser material sweeps the finer material down, particularly in the case of dense mixtures; hence the poor selective power, the bulky sediment, and hence we fail to arrive at values for the rates of subsidence of the thoroughly comminuted dust at all. In the tripoli employed I indeed measured particles microscopically[1] as large as 0.00005 centimeter to 0.0007 centimeter, but these are at once ejected by water as well as by ether, are found at the bottom before the surface of demarkation has fallen 0.05 centimeter, and have no bearing on the phenomenon in hand.

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[1] Slotte, Wied. Ann., XX, p. 262, 1883.

[2] Poiseuille, Ann. de Chim. et de Phys. (3), VII, p. 50, 1843; ibid., p. 76, 1847.

[3] Graham, Phil. Mag. (4), XXIV, p. 238, 1861.

Electrical relations.—If we compare the results for rate of precipitation taken from Tables 5 and 6, or from Table 10, with the known values of electrical conductivity of the respective solutions, we fail to find any detailed similarity in the two sets of data. In a general way, perhaps, the strong mineral acids show marked power to increase both rate of subsidence and electrical conductivity. But the salts of copper, of magnesium, and of zinc increase the rate of precipitation to a much larger degree than can be inferred from their electrical constants. Much of the discordance is no doubt to be referred to the coarseness even of the best available methods for measuring rates of subsidence. Chemical affinity produces a distortion; in the case of acids, for instance, effecting actual solution of particles of extreme fineness. But with due allowance for all these sources of error, I feel convinced that more elaborate experiments will not substantially change the results. Regarding this question from a theoretical point of view, greater accordance of results than has here been obtained is not at all to be anticipated. The electrical conductivity in case of dilute solutions is dependent on the friction against which the ion moves in its passage through water—a quantity which has not an immediate bearing on the subsidence of a small solid particle.

Precipitation increases in a marked degree with the amount of salt of a given kind in solution. This is equally true of electrical conductivity. Nevertheless, here again there is probably not perfect parallelism in the march of the two phenomena. The increase of conductivity for such (small) quantities of dissolved salt as are enumerated in the tables is regular and uniform. The rate of subsidence appears to increase very slowly, almost imperceptibly at first, until a certain amount of solid is dissolved; further additions are accompanied by rapid acceleration in the rates of subsidence. But this inference is liable to error, inasmuch as at the critical stage in question, surfaces of demarkation are no longer available.

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[1] The diffraction method applies, of course, only to much larger particles; at least the exceptionally large corpuscles which are just within reach of violet light fall too rapidly for uniformity of distribution. In connection with the values of R it is interesting to note that the dimensions of the vesicles of mist in the air as obtained by Fraunhofer, (Schumacher, Astr. Nachr., III, p. 62) and later by Kaemtz (Meteorologie, III, p. 111, Mousson, Phys., II, 1872), are 0.0017 centimeter and 0.0033 centimeter, respectively, the numbers varying with climatic conditions. It is well known that lycopodium spores (0.003 centimeter) and Bowista spores (0.0004 centimeter) come nicely within the range of the diffraction method.

My results on the relation of conductivity and sedimentation, when considered in the aggregate, may therefore be summarized thus: A similarity between corresponding data for electrical conductivity and rate of subsidence is roughly apparent when the change of internal energy of water is produced either by heat alone or by solution of different quantities of one and the same salt. Between the values of these variables obtained by dissolving different salts no relation is observable, except perhaps of a very general kind. In the case where precipitation takes place in different simple liquids (water, alcohol, ether) the respective rates differ enormously from the values which the conductivity of these substances would lead us to infer.[1]

In view of the fact that the degree of comminution of the particles under consideration is much smaller than the limit of microscopic visibility it is permissible to make this inference: The frictional resistance experienced by the solid particle in its passage through the liquid, although apparently constant, is no longer so when regarded with reference to its value during a number of consecutive indefinitely small times. If, furthermore, we admit that the limits within which this frictional force is comprehended increase with the degree of molecular agitation of the liquid, then the analogy between the phenomenon of electrical conductivity, as explained by Clausius, and the phenomenon of subsidence of extremely fine particles in liquids is very nearly complete: in one case the ion is sensibly acted on by an electromotive force during the times when it is relatively in a state of freedom as regards the powerful chemical attraction of surrounding molecules; in the other, the tendency of gravity to urge the particle downward produces an effect when its weight is temporarily greater than the variable friction encountered during its motion through agitated molecules. The ultimate result in the electrical experiment is the appearance of free ions at the electrodes; in the other experiment a sediment collects at the bottom of the tube.

Particles of larger dimensions.—I will introduce this paragraph by the following random selection from a large number of data. The table contains a comparison of the rates of subsidence in brine of 0 per cent., 0.5 per cent., and 1 per cent. strength, respectively, when in one case the original mixtures are densely turbid and opaque, in the other only just opaque fading into translucent; tubes, 3 cm. in diameter and 20 cm. long. In both sets of experiments I observe three different degrees of turbidity, in which the suspended material varies as 4 : 2 : 1 for each of the stated percentages of salt solution. *o.* denotes opaque, *tr.* translucent, *cl.* clear, as above. The depth of the opaque stratum is determined by noting the point of the tube at which a beam of the light of the sky reflected from a distant plane mirror and passing through the tube is extinguished. Depth is always given in millimeters below the meniscus as a datum; time, in hours (*h*).

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[1] Remarks of an analogous kind are made by those who have endeavored to express the electrical conductivity, k, in terms of the quantity, p, of salt dissolved and the viscosity, η, of the solution. Grotrian (Pogg. Ann., CLVII, p. 250, 1876) obtains good agreement (at 18° and 15°, respectively) by using the formula $k = c\frac{p}{\eta^n}$, where c and n are constants.

TABLE 11.—*Subsidence of opaque and of translucent mixtures in brine.*

Date.	*h*	Strength of brine =	NaCl, 0 per cent.			NaCl, 0. 5 per cent.			NaCl, 1 per cent.		
		Relative turbidity =	4	2	1	4	2	1	4	2	1
Oct. 3, 1885 ...	0	Densely opaque mixtures.	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*
	5.3		*o.*	*o.*	*o.*	*tr.*	*tr.*	*tr.*	*cl.*	*cl.*	*cl.*
Oct. 4, 1885 ...	21		*o.* 15	*o.* 25	*o.* 50	*cl.*	*cl.*	*cl.*	......	......	......
Oct. 6, 1885 ...	69		*o.* 50	*o.* 90	*o.* 160						
			Demarkation indistinct.			Particles fall in the ratio of turbidity and concentration, leaving a filmy opalescence behind; sediment, bulky and flocculent, collects at the same rate. Precipitation is complete in fractions of an hour.					
Oct. 1, 1885 ...	0	Dilute semi-translucent mixture.	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*	*o.*
Oct. 3, 1885 ...	38		No demarkation. Tubes approach translucency in the exact order of concentration and turbidity, being turbid still, although 1 per cent. is nearly clear. Effect of quantity of salt not very readily obvious.								
	48		*o.*	*o.* *tr.*	*tr.* *cl.*	*o.*	*tr.*	*tr.* *cl.*	*cl.*	*cl.*	......
Oct. 4, 1885 ...	63		*o.* *tr.*	*tr.*	*tr.* *cl.*	*o.* *tr.*	*tr.*	*tr.* *cl.*	*cl.*	*cl.*	......

This table reproduces an exceedingly striking observation in an unavoidably coarse and imperfect way. The action of the precipitant is marked and instantaneous when the solutions are densely turbid, I may add, in such a way as to contain relatively large corpuscles in suspension. When the turbidity is slight and the particles are fine, the tendency of salts to produce precipitation, however pronounced, is no longer quite so obvious.

Many of the particles here subsiding are probably too large to fall within the scope of the hypothesis enunciated in the preceding paragraph. But causes for the observed coherence of particles, the bulky and flocculent precipitates and the rapid subsidence seem to me not far to seek. The view which I advance provisionally is based on a principle similar to that by which Lesage, of Geneva, endeavored to explain the mechanism of gravitation. Suppose for a moment that the particles are without weight. If we regard any one of them individually, the effect of the molecular agitation would in general be nil so far as motion of the particle is concerned, inasmuch as this action is symmetrically distributed over the whole surface. If, however, there be given two particles, and if these be placed in sufficient proximity, then this symmetry of action is destroyed; the two particles will mutually screen or shield each other from impact on the parts of their surfaces which face each other, whereas the external parts of the surfaces are left exposed in full. The result is a force tending to move the particles together in a line joining their centers. In some such way, I believe, the larger particles in the presence of precipitants, or at higher temperatures (i. e., under conditions of intensified molecular disturbance at the surfaces of the particles), attract the finer particles, sweeping the greater number of them to the bottom of the tube at relatively large rates.

Subsidence and viscosity.—In this place the results in Tables 7 and 9, referring to ether, alcohol, and water, throw new light on the discussion. For the viscosities of these substances Poiseuille[1] found the relative data 0.3, 2.2, 1, respectively—where, however, the alcohol is not absolute, but an 80° (alcoholometer) spirit. Graham[2] finds the viscosities of water and alcohol in the ratio of 1 to 1.2. These values are proportional to the times occupied by the liquids in passing through identical capillary tubes under identical circumstances (transpiration). Now it would appear that in the case of subsidence we have quite an analogous experiment. In the first instance, a fine thread of liquid moves through a fixed solid; in the second, a fine particle of solid moves through a stationary liquid. In both cases the two substances move relatively to each other under conditions by which eddies are excluded, and the whole kinetic energy is at once converted into molecular kinetic energy or heat. Table 7, however, in connection with the results of Poiseuille and of Graham, shows conclusively that a relation between the rates of subsidence and the rates of transpiration is by no means apparent. The necessary inference is either that the frictions encountered in the two cases are radically different, or that the dimensions and the density of the particles change with the properties of the liquid in which they are submerged, or both. Above (p. 15) I accepted the last as the most probable conclusion; but it is nevertheless difficult and unsatisfactory to endeavor to make allowance for the observed enormous variations of rate of subsidence by simple variations of density and dimensions of the subsiding particles. These remarks are further exemplified by the results obtained with saline solutions.

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[1] Poiseuille, Ann. de Chim. et de Phys. (3), XXI, p. 104, 1847.

[2] Graham, Phil. Mag. (4), XXIV, p. 239, 1862.

The effect of the solution of the salts $CuSO_4$, $MgSO_4$, $ZnSO_4$, $NaCl$, and of the acids HCl, H_2SO_4 in water, at ordinary temperatures, is an increase of the viscosity of the liquid nearly proportional (where, as in the above tables, only fractions of a per cent. are dissolved) to the quantity of salt or acid in solution.[1]

There are some salts,[2] notably among them KI, the viscosity of whose weak solutions at low temperatures is less than the viscosity of water. But the value of the decrement produced by addition of quantities as small as 0. 1 per cent. is in no case phenomenal or even large. Table 6, moreover, shows no marked difference between the respective rates of subsidence in solutions of KI and of NaCl, whereas in the first instance the viscosity of water has been increased, in the second diminished, by the solution of like quantities of the two salts. To me it appears impossible that additions of small fractions of a per cent. of acid or of salt to water should be able to affect the mean or measurable viscosity of this liquid in any marked degree; certainly not to such an extent as increases the rate of subsidence even many hundred fold.[3]

CONCLUSION.

In the above pages I have endeavored to throw light on the phenomenon of subsidence from three points of view. I adverted in the first place to the mechanical conditions of subsidence, i. e., to the dependence of rate of descent upon the figure and physical constants of a single particle or upon the constants of a stated group of particles. I then attempted to point out certain possible analogies in the sedimentation of very fine material with Clausius's interpretation of electrolysis—to find some expression for the dependence of subsidence on the molecular conditions of the liquid. Finally, I called to mind the probability of certain permanent chemical effects of the liquid on the subsiding solid. The last of these subjects of inquiry is more nearly open to investigation, independently of the others, than either the first or second. This, therefore, seems to be the proper point of departure for further research; and I believe, if the relations in question are systematically studied, that the quantitative results will not only elucidate many obscure points of the chemical behavior of solids,[1] but that they will even furnish data bearing directly upon the phenomenon of solution. Solution is here the limit of turbidity.[2] Indeed, I know not whether the degree of extreme divisibility of subsiding particles, or even the mean size of the particles of an ordinary precipitate, has ever been *systematically* put into relation with the conditions, physical and chemical, under which subsidence takes place.

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[1] The literature of the viscosity of liquids since the original memoirs of Girard (Mém. de l'Acad. Roy. de l'Inst. de France, 1816) and by Poiseuille (Ann. de Chim. et de Phys. (3), VII, p. 50, 1843; ibid., p. 76, 1847) has been steadily increasing, though the more important additions are of recent date. The reader desiring further information is referred to the papers of Sprung, Pogg. Ann., CLIX, p. 1, 1876; Grotrian, Pogg. Ann., CLII, p. 1, 1876; ibid., CLX, p. 1, 1877; Wagner, Wied. Ann., XVIII, p. 259, 1883, and others. Grotrian studies the vibration about a vertical axis of a very large horizontal disk suspended in a liquid, the theory of which experiment is fully known. In other researches, however, Grotrian, in common with the remaining physicists, adopts the more accurate method of transpiration. See Graham, "On liquid transpiration, etc.," Phil. Mag. (4), XXIV, p. 238, 1861.

[2] NH_4Cl, NH_4NO_3, NH_4Br, KI, KBr, KNO_3, KCl (Sprung, l. c.), $BaNO_3$ (Wagner, l. c.).

[3] Similar remarks may be made with reference to the capillary and cohesion constants of liquids, those of Gay Lussac, for instance. Cf. Mousson, Physik, I, pp. 263, 267, 1871.

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[1] The tendency to hydration under varying conditions of mass per unit volume of liquid, for instance.

[2] See above, page 12, and chapter II, p. 42.

CHAPTER II.

THE DEPENDENCE OF RATE OF SUBSIDENCE ON ORDER OF SURFACE, CONCENTRATION, AND TURBIDITY.

EXPERIMENTAL RESULTS.

Introductory.—In this chapter it is my object to begin a minute study of the conditions subject to which a column of turbid liquid must present a stratified appearance. The turbidity is assumed to be due to very finely comminuted insoluble matter which the liquid holds in suspension.

The strata in question are usually characterized by sharp upper surfaces, below which opacity decreases until a depth is reached at which another surface juts out, as it were; from this point, downward, turbidity decreases again as far as the next consecutive surface, and so on for the remaining surfaces. Particles are thus aggregated on every surface and near it from below. If we suppose depth to be laid off vertically downward and opacity horizontally to the right, the appearance of the tube would be well given by a saw placed so that the cutting edges of the teeth may be upward on the right and nearly horizontal; in other words, the serrated outline of the diagram passes from left to right downward, indicating a general increase of opacity from top to bottom of the column. I need only add that the continuous decrease of opacity for parts of the column between the first and second, second and third surfaces, &c., is not so marked as between consecutive lower surfaces.

It has been stated above (p. 20) that in the case of fresh material the surfaces in question do not seem to appear until after the lapse of a large interval of time, say one to two hundred hours; but when the particles have just undergone subsidence, strata may be obtained sooner. Again, the occurrence of pronounced stratification is observable sooner with semitranslucent than with very opaque mixtures; in the latter case they eventually appear in greater number than in the former. Finally, after the strata have come into distinct definition, they retain their individuality until they ultimately vanish, or, at least, become too faint for measurement. Fluctuation of temperature interferes with sharpness of outline. In the present paper, however, some of the experiments have extended over 1,200 hours, so that the aggregated effect of temperature is probably nil.

The general method by which I hope to arrive at definite results on the ultimate cause of stratification consists in a minute study of the rate at which subsidence takes place considered in its dependence upon the order of the surface, the concentration, and the turbidity of the solution. It will be convenient to number the surfaces from the top downward, and distinguish them as surfaces of the first, second, third ...... order. Under concentration is to be understood the number of grams of dissolved precipitant per cubic centimeter of solution; under turbidity, similarly, the number of grams of insoluble dust of a given kind per cubic centimeter of solution. In the present experiments, however, it has been expedient to express turbidity arbitrarily.

Data.—Tripoli suspended in distilled water or in weak brine subsides at rates of practically convenient magnitude. This mixture has therefore been used in the present work.

The first series of results refers to diluted, i. e., to semitranslucent mixtures. The degrees of concentration vary from 0 to 1 per cent. of salt. For each strength of brine, moreover, three degrees of turbidity in the ratio of 4:2:1 are observed. The following Table 12 is a clear exhibit of the contents of the several tubes, the data indicating the number of cubic centimeters of turbid water, brine, and clear water mixed in each case.

TABLE 12.—*Semitranslucent mixtures — contents of tubes.*

Ingredients.	0 per cent.			0.1 per cent.			0.2 per cent.		
	4	2	1	4	2	1	4	2	1
Tripoli water.............cubic centimeters.	40	20	10	40	20	10	40	20	10
Brine............................do	0	0	0	1	1	1	2	2	2
Distilled water ....do	10	30	40	9	29	39	8	28	38

Ingredients.	0.4 per cent.			0.6 per cent.			0.8 per cent			1 per cent.		
	4	2	1	4	2	1	4	2	1	4	2	1
Tripoli water ....cubic centimeters.	40	20	10	40	20	10	40	20	10	40	20	....
Brine.................................do	4	4	4	6	6	6	8	8	8	10	10	....
Distilled water ....do	6	26	36	4	24	34	2	22	32	0	20	....

Tripoli water used after standing three days.
Brine: 10 grams in 200 cubic centimeters.
Tubes (diameter, 25mm.; length, 200mm.) shaken up simultaneously October 1, 1985, 6 p. m.

Table 13 gives the results obtained with these mixtures; column first contains the date; column second, the time in hours elapsed since the beginning of the experiment; the remaining columns indicate the depth in millimeters of the surfaces of demarkation, for the condition of concentration and turbidity given at the column heading, below the surface of the liquid as a datum. Whenever the column shows a number of surfaces (surfaces of different orders), the depth of each is noted, the data being placed vertically above one another, in proper sequence; *c.* denotes clear.

TABLE 13.—*Semitranslucent mixtures—consecutive positions of the surfaces of demarkation.*

Date.	Time of day.	*h*	0 per cent.			0.1 per cent.			0.2 per cent.		
			4	2	1	4	2	1	4	2	1
October 1, 1885	6 p. m	0	0	0	0	0	0	0	0	0	0
October 6, 1885	7 p. m	121	20	40	70	23	52	80	25	42	72
October 8, 1885	10 a. m	160	26	45	85	27	65	97	32	53	92
			50	90	....	45	100	....	45	90	....
			70	......	....	70	......	......	61	......	....
			90	.....	....	100	......	......	90	......	....
October 9, 1885	10 a. m	184	32	54	90	35	74	112	35	60	105
			58	100	....	53	120	......	55	......	....
			80	......	....	82	.....	......	74	......	....
			100	.....	....	115	.....	......	105	...	...
October 10, 1885	10 a. m	208	35	59	c.	38	82	c.	44	70	c.
			65	110	....	59	......	......	84	......	....
			90	......	..	92	......	......	......	......	....
			115	......	....	......	......	......	.....	......	....
October 11, 1885	10 a. m	232	40	65	c.	42	95	c.	50	82	c.
			75	......	..	67	......	......	98	....	....
						102					
October 12, 1885	12 m	258	44	72	c.	45	102	c.	57	80	c.
			80	......	..	75	......	......	105	......	....
October 13, 1885	1 p. m	283	49	77	c.	50	110	c.	64	98	c.
			89	......	..	82	......	......	......	......	....

Date.	Time of day.	*h*	0.4 per cent.			0.6 per cent.			0.8 per cent.			1 per cent.		
			4	2	1	4	2	1	4	2	1	4	2	1
October 1, 1885	6 p. m	0	0	0	0	0	0	0	0	0	0	0	0	....
October 6, 1885	7 p. m	121	40	60	c.	65	90	c.	100	c.	c.	c.	c.	....
October 8, 1885	10 a. m	160	50	75	c.	85	110	c	c.	c.	c.	c.	c.	....
			89	....	....	....	....	....	....	....	....	....	....	....
October 9, 1885	10 a. m	184	60	83	c.	c.	c.	c.	c.	c.	c.	c.	c.	....
October 10, 1885	10 a. m	208	72	c.	c.	c.	c.	c.	c.	c.	c.	c.	c.	....
October 11, 1885	10 a. m	232	85	....	....	....	....	....	....	....	....	....	....	....
October 12, 1885	12 m	258	95	....	....	....	....	....	....	....	....	....	....	....
October 13, 1885	1 p. m	283	105	....	....	....	....	....	....	....	....	....	....	....

Table 14, finally, contains data for the rates of subsidence of each of the divers orders of surfaces, degrees of concentration and degrees of turbidity given in Table 13. Rates are expressed in $\frac{mm}{h}$. To derive these results I used graphic methods. The accuracy thus obtainable is fully in keeping with the accuracy of the other work.

TABLE 14.—*Semitranslucent mixtures—rates of subsidence.*

Order of surface.	0 per cent.			0.1 per cent.			0.2 per cent.		
	4	2	1	4	2	1	4	2	1
1	0.16	0.28	0.54	0.18	0.40	0.63	0.23	0.35	0.57
2	0.32	0.54	......	0.28	0.64	......	0.30	0.56	......
3	0.44	....	......	0.44	......	......	0.40	......	......
4	0.56	......	......	0.62	......	......	0.57	......	......

Order of surface.	0.4 per cent.			0.6 per cent.			0.8 per cent.		
	4	2	1	4	2	1	4	2	1
1	0.35	0.46	......	0.54	0.71	......	0.82	......	......
2	0.56	......	......	......	......	......	......	......	......
3	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	......

The next three tables are constructed on a plan identical with that pursued in the cases of Tables 12, 13, and 14. Time, *h*, is given in hours, depth in millimeters, rate of subsidence in $\frac{mm}{h}$. In addition to the experiments with water, it was found convenient to compare the rates of subsidence in pure water and in water charged with alcohol and with ether, respectively, in the proportions specified in the last four columns of Table 15.

TABLE 15.—*Opaque mixtures—contents of tubes.*

Ingredients.	0 per cent.			0.5 per cent.			1 per cent.			Alcohol.		Ether.	
	4	2	1	4	2	1	4	2	1	W.	A.	W.	E.
Tripoli water....cubic centimeters..	60	30	15	60	30	15	60	30	15	60	60	70	70
Brine........................do......	0	0	0	8	8	8	16	16	16	......	....	......	......
Distilled water..............do......	16	46	61	8	38	53	0	30	45	20	......	10	......
Alcohol......................do......	....	....	....	...	....	....	....	....	....	......	20	......	......
Ether........................do......	....	....	....	...	....	....	..	....	....	......	......	......	10

Tripoli water, densely opaque.
Brine, 10 grains in 200 cubic centimeters.
Tubes (diameter, 25 mm.; length, 200 mm.) shaken up simultaneously October 3, 1885, 12 m.

TABLE 16.—*Opaque mixtures — consecutive positions of the surfaces of demarkation.*

Date.	Time of day.	*h*	0 per cent.			0.5 per cent.			1 per cent.			Alcohol.		Ether.	
			4	2	1	4	2	1	4	2	1	W.	A.	W.	E.
October 3, 1885	12 m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
						Subsidence takes place in the ratio of concentration and turbidity, and is almost complete in fractions of an hour. No demarkation.									
October 10, 1885	10 a. m.	166	10	17	25										
			....	(*a*)	65										
			....	....	90										
			....	....	110										
October 11, 1885	10 a. m.	190	13	22	30										
			....	60	67										
			....	75	100										
			....	95	120										
October 12, 1885	12 m.	216	15	27	34	....	....	....	....	....	....	...	(*b*)	....	(*b*)
			....	70	80										
			....	85	110										
			....	104	145										
October 13, 1885	1 p. m.	241	10	30	40										
			....	52	87										
			(*a*)	65	120										
			....	80											
			....	100											
			....	125											
October 14, 1885	5 p. m.	269	22	35	45										
			....	55	97										
			....	70	140										
			...	90											
			....	110											
			....	140											
October 16, 1885	9 a. m.	309	25	28	52	....	....	....	...	....	....	30	60	23	(*b*)
			38	65	111	....	....	..	...	....	....	50	(*b*)	34	
			50	78	....	....	....	....	....	....	....	63			
			63	100	....	....	....	....	....	....	....	77			
			73	125											
			85												
			105												
October 17, 1885	2 p. m.	338	29	42	60	....	....	....	..	....	...	41	...	25	
			44	70	123	....	....	...	..	..	..	56	...	37	
			56	85	....	....	....	....	..	....	..	74			
			60	110	....	....	....	...	....	...	..	88			
			81	138											
			95												
			112												
October 19, 1885	9 a. m.	381	33	40	68	....	.	..	...	....	....	45	72	31	
			53	80	135	....	..	.	....	....	....	65	....	44	
			66	96	....	....	....	...	..	...	....	84			
			80	124											
			90												
			107												
			120												

a Incipient stratification.

b Column turbid.

TABLE 16.—*Opaque mixtures—consecutive positions of the surfaces, &c.*—Continued.

Date.	Time of day.	*h*	0 per cent.			0.5 per cent.			1 per cent.			Alcohol.		Ether.	
			4	2	1	4	2	1	4	2	1	W.	A.	W.	E.
October 20, 1885	8 a. m.	404	34	50	74	....	....	....	....	....	....	50	75	32	
			55	84	....	....	....	....	....	....	....	70	....	45	
			70	100	....	....	....	....	....	....	....	90			
			85	130											
			98												
			117												
			138												
October 21, 1885	8 a. m.	428	38	55	75	....	....	....	....	....	....	51	....	38	
			59	90	....	....	....	....	....	....	....	71			
			75	111	....	....	....	....	....	....	....	92			
			90	136											
			103												
			122												
			145												
October 22, 1885	8 a. m.	452	30	59	80	....	....	....	....	....	....	54	82	39	
			62	95	....	....	....	....	....	....	....	75	....	54	
			80	....	....	....	....	....	....	....	....	100			
			95												
			108												
			128												
			152												
October 23, 1885	12 m.	480	40	60	85	....	....	....	....	....	....	57	87	40	
			65	100	....	....	....	....	....	....	....	84	....	60	
			85												
			104												
			117												
			137												
October 24, 1885	2 p. m.	500	45	66	90	....	....	....	....	....	....	64	91	44	
			70	107	....	....	....	....	....	....	....	90	....	65	
			89												
			109												
			122												
			145												
October 25, 1885	9 a. m.	525	45	68	93	....	....	....	....	....	....	65	95	45	
			72	110	....	....	....	....	....	....	....	92			
			92												
			113												
			125												
			147												
October 26, 1885	8 a. m.	548	46	70	99	....	....	....	....	....	....	65	96	47	
			74	118	....	....	....	....	....	....	....	95			
			95												
			119												
			130												
October 27, 1885	8 a. m.	572	50	74	101	....	....	....	....	....	....	70	100	50	(a)
			78	120	....	....	....	....	....	....	....	98			
			100												
			125												
			135												

[a] Column turbid.

TABLE 16.—*Opaque mixtures—consecutive positions of the surfaces, &c.*—Continued.

Date.	Time of day.	*h*	0 per cent.			0.5 per cent.			1 per cent.			Alcohol.		Ether.	
			4	2	1	4	2	1	4	2	1	W.	A.	W.	E.
October 28, 1885	8 a. m..	596	51	75	110	....	....	....	...	...	....	72	103	51	
			80	125	...	....	....	....	....	....	....	102			
			102												
			128												
			141												
October 29, 1885	1 p. m..	625	55	80	112	....	....	....	....	....	....	74	107	51	
			85	131	....	....	....	....	....	....	....	106			
			108												
			134												
			140												
October 31, 1885	0 p. m..	681	59	85	118	...	....	....	....	....	....	80	113	56	
			91	140											
			118												
			141												
November 2, 1885	10 a. m..	718	62	91	124	...	....	....	....	....	...	83	118	59	
			97	149											
			125												
November 3, 1885...........	8 a. m..	740	63	91	126	....	....	....	....	....	....	86	120		
			99												
			126												
November 5, 1885...........	7 a. m..	787	103	99	133	....	....	....	....	....	....	90	124		
			133												
			67												
November 9, 1885...........	12 m	888	79	110	147										
			118												
			149												
November 13, 1885..........	0 p. m..	993	87	127	(*a*)										
			129												
November 23, 1885..........	6 p. m..	1,230	104	145	(*a*)	....	...	...	....	....	....	...	(*b*)	...	(*b*)
			150												

a Clear.

b Column turbid.

TABLE 17.—*Opaque mixtures—rates of subsidence.*

Order of surface.	0 per cent.			Water.		Ether.	
	4	2	1	W.	A.	W.	E.
1...............	0.08	0.12	0.17	0.12	0.17	0.08	......
2...............	0.13	0.20	0.36	0.17	....	0.12	......
3...............	0.17	0.25	0.51	0.22	.....	......	......
4...............	0.21	0.32	0.65	0.25	....	.....	......
5...............	0.24	0.40	......	....	.....	......	......
6...............	0.28	0.51	......	......	......	......	......
7...............	0.33	... .	......	......	......	.....	......

A few remarks on these tables are in place here. The observation that distinct stratification is an earlier occurrence in translucent solutions than in very opaque solutions is well shown by the data in Table 16. The alcohol and the ether solutions remain turbid during the whole of the 1,230 hours within which subsidence is in progress. The descending surface in alcohol (very dense) must therefore be of an order higher than the first. Possibly the persistent turbidity may be connected with slow evaporation of alcohol or of ether out of the solvent water. Where subsidence takes place too rapidly for the formation of surfaces, no data are given, since those results would not be comparable with the other data, and the qualitative character of the phenomena has already been fully given in Chapter I.

The term translucent solution is used interchangeably with diluted mixture, opaque solution interchangeably with dense mixture. The extreme members of the dilute and of the opaque series differ largely in turbidity; but the degrees of turbidity of the intermediate members (i. e., high degrees for translucent solutions and low degrees for opaque solutions) probably overlap.

DEDUCTIONS.

The discussion may expediently be made to conform with the general plan pursued in the experiments. Rate of subsidence is therefore to be studied with regard to its dependence on order of surface, on concentration, and on turbidity.

Surfaces of different orders.—Turning first to the data for diluted mixtures, Table 14, I find three series of results available for comparison. In these there appears a distinct tendency of rate of subsidence to augment by nearly the same increment on passing each of the consecutive surfaces of demarkation. In the case of one and the same column, therefore, like differences of order correspond approximately to like differences of rate. This deduction is nearly true for the 0 per cent. solutions, and true to a smaller extent for the 0.1 per cent. and 0.2 per cent. solutions.

It is remarkable that as far as the 0.6 per cent. brines, the lowest surfaces for all turbidities and concentrations have like rates. This, however, may be merely accidental, so that if the tubes had been of greater length the result would no longer hold. Any rate in turbidity 1 is, as a rule, repeated in turbidity 2; rates in turbidity 2 are repeated in turbidity 4. When turbidity decreases, greater rates are more frequently repeated than smaller rates. We are thus inclined to infer that for continued dilution the column of finer material eventually becomes so nearly transparent that the surfaces escape detection; but this explanation is not valid, as will be shown presently in the case of opaque mixtures. For brine of greater strength than 0.6 per cent. the observations lose in accuracy, and we begin to encounter marked evidences of the effect of salt. Finally the increment of rate from surface to surface is augmented in marked degree in proportion as the turbid column approaches translucency.

With these suggestive results in hand it is well to turn for further corroboration to the experiments upon opaque solutions given in Table 17. The three degrees of turbidity of the 0 per cent. solutions, as well as the water of the alcohol and the ether series, are here available for comparison. The evidence given by all of these corroborates the deductions made above in a very satisfactory manner, viz: for one and the same turbid column the rate of subsidence tends to increase, step by step, in regular order, downwards. If mere dilution were of moment here, the upper layers would subside fastest. The column, which at the outset is continuously opaque, splits up into periods of nearly the same value. Again, the increment of rate of subsidence corresponding to two consecutive surfaces is manifestly smaller for opaque than for translucent solutions, and varies quite regularly with the degree of turbidity. This result is fully confirmed by the data for dilute solutions.

The very satisfactory accordance of all data in hand may be shown graphically by regarding rate of subsidence as a function of order of surface and constructing the linear loci on which the isolated points of observation approximately lie. This has been done in the annexed Fig. 3. If these lines taken as a whole be prolonged in the direction of order decreasing, we infer from the positions of the divers points of intersection with the axis X, that probably only one or at most two surfaces of very slow rate have escaped detection. Whether or not such prolongation be permissible remains to be seen, but the particles belonging to one of these surfaces are probably the cause of the permanent opalescent turbidity which frequently remains after measurable subsidence is complete.

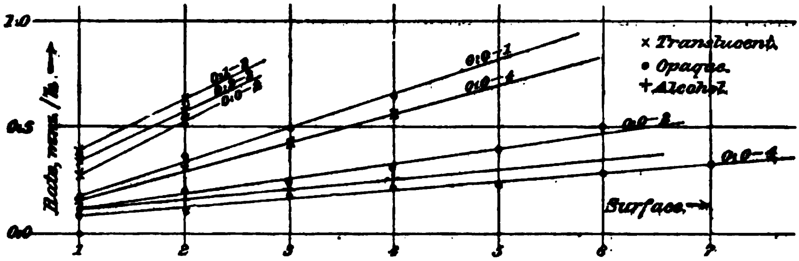

FIG. 3.—Relation of rate of subsidence to order of surface for different degrees of turbidity.

Concentration.—In the case of dilute mixtures turbidity 4, surfaces 1 and 2, and turbidity 2, surfaces 1, are available. It appears that rate of subsidence as a function of concentration varies at a gradually accelerated rate, almost imperceptibly between 0 per cent. and 0.2 per cent.; more rapidly from 0.2 per cent. on. Surfaces are obtainable even as far as 1 per cent. In the case of very opaque solutions surfaces are no longer obtainable even for brine of a few tenths per cent. of strength. Here, therefore, rate of subsidence increases with concentration much more rapidly than holds for dilute mixtures.

Turbidity.—In the case of opaque solutions the six consecutive surfaces of the 0 per cent. series are available. The data show that velocity of subsidence diminishes at a gradually decreasing rate as turbidity increases. This diminution is more pronounced for the upper rapidly-falling surfaces than for the lower surfaces of slower descent. Regarded as a whole, therefore, the curves converge more and more nearly in proportion as the original column is more opaque (Fig. 4). Hence for very opaque solutions, cæteris paribus, the curves probably converge in the rate of subsidence zero. In other words, the tendency is toward permanent opacity without stratification.

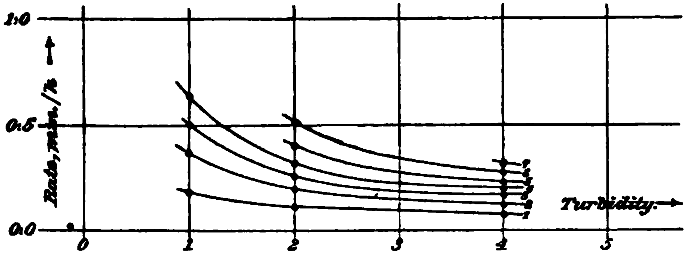

FIG. 4.—Relation of rate of subsidence to turbidity for consecutive orders of surfaces.

All these inferences are sustained by the data in hand for translucent solutions, where first surfaces of the 0.0, 0.1, 0.2, 0.4 per cent. solutions, and second surfaces of the 0.0, 0.1, and 0 2 per cent. solutions have been compared. Unfortunately, the results for opaque and for dilute solutions are on a different scale of turbidity. It is a question, moreover, whether surfaces of like order can be at once co-ordinated, so that further inquiry into this subject will be desirable and fruitful.

Temperature.—It has already been pointed out, as a result of the error introduced by temperature, that the actual locus does not necessarily pass through the origin. This assumption, therefore, is only partially correct. It is, however, the only method of representation which may be consistently applied throughout. I may add, that, columns of liquid placed side by side, show parallel variations of temperature discrepancy. If the surfaces observed above were due to temperature only, then we ought to find traces of a daily effect. In the 1,230 hours of examination, therefore, fully fifty such surfaces should be anticipated. The phenomenon observed is essentially different from this.

Sedimentation battery.—The experiments made suggest the following scheme for researches of a final kind: The tubes for subsidence should be 50 cm. long and about 3 cm. wide. This will give assurance not only that all surfaces have been detected, but will enable the observer to follow each one through a large interval of descent. These tubes (36 to

100) are to be conveniently arranged in tiers of say 6 to 10 in each horizontal row and the same number in each vertical row. Where brine and tripoli, for instance, are the ingredients, the degrees of concentration 0.0, 0.1, 0.2, 0.4, 0.6, 0.8, 1 per cent. (horizontal row) and the degrees of turbidity 1, 2, 4, 6, 8, 10 (vertical row) will probably suffice to enable the observer to follow all the essential phenomena closely. It is highly desirable that each tube be provided with a millimeter scale (etched). It is necessary that the battery be placed in a room whose temperature is constant. Great pains must be taken to detect and observe all surfaces, and even to seek for such as are apparently invisible, by some such method as that described in the text, page 49. The experiments must, of course, be extended to a variety of subsiding solids. They must frequently be repeated to exhibit the time effect of the action of the liquid on the suspended solids.

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